

Beyond Matching Targets: An Approach to Outcome Evaluation in Pediatric Hearing Aid Fitting

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Introduction

Pediatric hearing aid fitting is a process that includes several stages: the calculation of prescriptive targets based on accurate hearing assessment information; the selection of the physical and electroacoustic elements of a hearing aid; verification that the specified acoustical prescriptive targets have been achieved; and outcome evaluation of device effectiveness in daily life. Of these stages, outcome evaluation does not currently have a systematic approach described in many pediatric hearing aid fitting protocols. Most protocols do, however, mention the importance of monitoring outcome even when specific strategies for doing so are not provided (i.e., College of Audiologists and Speech Language Pathologists of Ontario [CASLPO] 2002; American Academy of Audiology [AAA] 2003; Modernising Children's Hearing Aid Services [MCHAS] 2005; British Columbia Early Hearing Program [BCEHP] 2006; Bagatto, Scollie, Hyde and Seewald 2010). This is likely due to the lack of evidence to support the systematic use of an outcome evaluation guideline for pediatric patients who wear hearing aids. Evaluating the outcome of the hearing aid fitting helps to answer the important question: "How do I know if the hearing aids are helping the child?" This question, either from the caregiver or professional, could be addressed by a well-validated, clinically feasible monitoring protocol to track auditory development and performance. Known clinical tools with

good normative properties, validity, feasibility, and utility would support the development of an evidence-based outcome evaluation guideline for pediatric audiology programs. Additionally, indicators to track clinical process outcomes, such as the appropriateness of the hearing aid fitting, are needed so that the functional outcomes can be appropriately interpreted.

The hearing aid fitting process is comprised of assessment, hearing aid selection and fitting, verification and outcome evaluation stages. For the youngest children receiving audiological services, refinements to the first three stages of the hearing aid fitting process have been completed over the past several years. Therefore, recent attention has been placed on developing and evaluating a clinical guideline that focuses on the evaluation of auditory performance in infants and children who wear hearing aids. Outcome evaluation, the fourth and final stage, completes the hearing aid fitting process by providing valuable information about the impact of the child's hearing aid fitting, potentially leading to a re-evaluation of the previous stages. This chapter presents a newly-developed guideline for outcome evaluation for use with infants and children who wear hearing aids. The development and contents of the University of Western Ontario Pediatric Audiological Monitoring Protocol version 1.0 (UWO PedAMP v1.0) will be described and data for children with normal hearing and aided hearing loss will be provided to support its clinical use.

Development of the UWO PedAMP v1.0

The UWO PedAMP was developed using an integrated knowledge-to-action (KTA) process framework (Graham et al. 2006; Straus, Tetroe and Graham 2009; Harrison, Légaré, Graham and Fervers 2010). The KTA framework, as illustrated in Figure 1, is comprised of a

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knowledge creation funnel and application of knowledge cycle. The knowledge creation funnel guides the creation of knowledge through several important filtering phases with the end goal being the development of tailored knowledge products and tools such as clinical practice guidelines (CPGs), that have the potential to be useful to end users (Graham et al. 2006; Straus et al. 2009; Harrison et al. 2010). Throughout the development of the UWO PedAMP, the creation of knowledge was defined as the social collaboration and negotiation of different perspectives, including personal experience, empirical evidence and logical deduction that concluded with acceptance of a common result (Stahl 2000). This definition makes it clear that knowledge creation is collaborative, never absolute and is subject to change based on future evidence, new questions, interpretation, and negotiation.

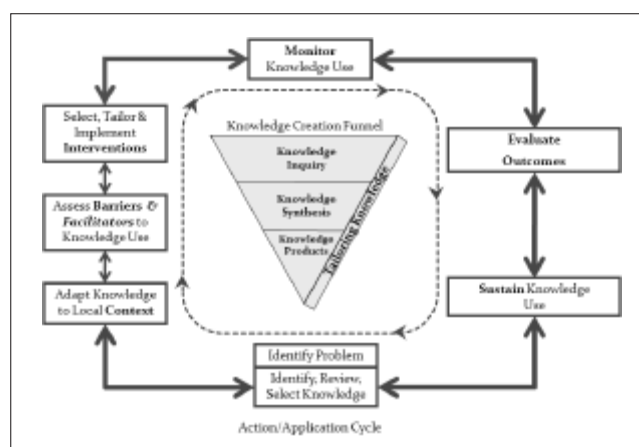


Figure 1. The knowledge-to-action (KTA) framework (Graham et al. 2006). Used with permission.

Research has shown that knowledge, in the form of CPGs, protocols and procedures will not be implemented into clinical practice merely because they make sense and meet specified needs. They will require a substantive proactive effort for knowledge translation to occur (Graham et al. 2006; Harrison, Graham and Fervers 2009; Harrison et al. 2010). Therefore the KTA framework includes a second, equally important component called ‘the action cycle’ (Graham et al. 2006; Harrison et al. 2009; Harrison et al. 2010). The action cycle of the KTA process facilitates the science of clinical implementation. It identifies the activities that should be considered to guide the application of the knowledge in clinical practice including: adapting the evidence, knowledge and research for use in local contexts; assessing the barriers and facilitators to the use

of the knowledge; selecting, tailoring and implementing interventions to ease and promote the use of the knowledge by clinicians; monitoring the use of knowledge; evaluating functional and process outcomes of using the knowledge; and developing methods to sustain ongoing knowledge use (Graham et al. 2006).

Knowledge Inquiry and Synthesis for the UWO PedAMP

In the knowledge inquiry and synthesis stages of the KTA process, a critical review of available outcome evaluation tools within the category of caregiver-report questionnaires was conducted (Bagatto, Moodie, Seewald, Bartlett and Scollie In Press). This allowed for an appraisal of the current tools to eliminate the need for developing new tools. Through the critical review process, there was an attempt to include tools with good statistical properties and available norms and avoid tools that were too lengthy or complicated in favor of those that had good clinical feasibility and utility.

Creation of the Tailored Knowledge Product

After completion of the inquiry and synthesis stages, authors of the UWO PedAMP set out to develop a tailored knowledge product that would be implemented into clinical use. Using the KTA process framework, 25 members of the Network of Pediatric Audiologists of Canada were invited to review the proposed outcome evaluation tools and provide objective and subjective feedback regarding the components of the UWO PedAMP v1.0. Their feedback was also requested regarding barriers and facilitators to implementing outcome evaluation tools within the contexts in which they worked. This provided an opportunity to use an engaged community of practice with a shared understanding of the knowledge and clinical needs. It also allowed the authors of the UWO PedAMP to strike a balance between creating an evidence-based guideline, which can be rigid and complex, with a more actionable, flexible guideline through the development of clear and specific tools (Bhattacharyya, Reeves and Zwarenstein 2009).

Benefits of Using the KTA Process Framework for the Development of the UWO PedAMP v1.0

The use of the KTA process framework during the development of the UWO PedAMP provided numerous ben-

efits. Collaboration with engaged and knowledgeable end-users enabled identification of desired modifications to the outcome evaluation tools early on in the process, along with development of other knowledge products (e.g., clinical summary sheets) that would facilitate clinical implementation of the tools. Pediatric audiologists noted the importance of visual tools to permit rapid scoring and appropriate normative data to support interpretation of scores. In addition, useful information regarding barriers to clinical use was obtained up front so that the authors might work before and during an implementation phase to reduce or eliminate them. For example, clinicians provided a substantial list of languages that they wanted the outcome evaluation tools translated into, including Arabic, Mandarin, Tamil and Urdu. This allowed the translation process to be started as early as possible so that when the tools were ready for wide-spread implementation, the most frequently requested languages for translation were completed or close to completion. Finally, by attending to many of the components of the KTA framework 'up front' during the development process, it was hoped that improvement of the implementation of the UWO PedAMP into clinical practice would be more successful than the small to moderate implementation effects currently reported in the CPG uptake literature (McCormack et al. 2002; Rycroft-Malone et al. 2002; Rycroft-Malone 2004; Rycroft-Malone et al. 2004; Hakkennes and Dodd 2008; Eccles et al. 2009; Wensing, Bosch and Grol 2009).

In summary, the UWO PedAMP was developed with input from pediatric audiologists from the beginning of development, while providing support from current evidence from the literature. As such, this guideline targets infants and children from birth to 6 years of age with hearing loss who wear hearing aids, and focuses on auditory-related behaviors in the early stages of hearing aid use. Additionally, the tools included in the UWO PedAMP aim to be appropriate for administration by the audiologist. While speech and language measures are considered an important part of evaluating a child's outcome with hearing aids, they are often more appropriately administered and scored by another professional (e.g., speech-language pathologist). It is hoped that the UWO PedAMP will support family-centered practice and allow clinicians to collaborate better with others involved with the child.

Contents of the UWO PedAMP v1.0

The first version of the UWO PedAMP includes outcome evaluation tools that aim to measure auditory-re-

lated outcomes in infants and young children who wear hearing aids including: subjective assessment of early auditory development; and subjective ratings of auditory performance in daily life. Additionally, clinical process outcome measures that assess the appropriateness of the hearing aid fitting and satisfaction with services are also included. While objective measures of sound awareness and subjective judgment of early speech production are considered important aspects of an outcome evaluation guideline, they were not the focus of this early work. The UWO PedAMP consists of the:

- Ontario Infant Hearing Program (OIHP) Amplification Benefit Questionnaire
- Hearing Aid Fitting Summary
- Aided Speech Intelligibility Index (SII) Normative Values
- LittEARS® Auditory Questionnaire (Tsiakpini et al. 2004)
- Parents' Evaluation of Aural/Oral Performance of Children (PEACH) Rating Scale (Ching and Hill 2005a)

The UWO PedAMP is intended to be used with children with permanent congenital hearing impairment (PCHI) from birth to age 6 years who wear hearing aids. Monitoring children with PCHI who do not wear hearing aids is also considered an important use of the UWO PedAMP; however, it is not the focus of this chapter. The proposed use may change as the guideline evolves through systematic evaluation and clinical implementation. The following sections provide an overview of each tool, as well as suggested administration guidelines and data from children with normal hearing and aided PCHI.

Administration of the UWO PedAMP in an Early Hearing Detection and Intervention (EHDI) Program

The Ontario Infant Hearing Program (OIHP) is an example of a comprehensive EHDI program which identifies children born deaf or hard of hearing and provides the supports and services they need to develop the language and literacy skills necessary to achieve success in school. The program provides services for children from birth to 6 years of age who are identified with PCHI and their families/caregivers. As well, it monitors those children born with, or who acquire, risk indicators for permanent hearing loss throughout early childhood. Program protocols are in place to provide universal newborn hearing screening, audiological assessment for

those babies who do not pass the screening, and amplification and communication development services for children found to be deaf or hard of hearing.

The majority of children with PCHI enrolled in the OIHP use hearing aids to facilitate the development of communication skills and readiness for school (Bagatto, Scollie et al. 2010). Measuring the impact of the hearing aid fitting is important for tracking an individual child’s progress as well as evaluating the program as a whole. The outcome evaluation tools within this version of the UWO PedAMP provide a systematic method for monitoring children enrolled with PCHI. This section will describe the clinical administration of the UWO PedAMP and includes: 1) administration guidelines for infants and children with aided PCHI (Figure 2); 2) a description of the OIHP Amplification Benefit Questionnaire; and 3) preliminary data from the OIHP Amplification Benefit Questionnaire. Information and data related to the Hearing Aid Fitting Details, the LittEARS, and the PEACH questionnaires are provided in the sections that follow.

To facilitate a smooth introduction of this guideline as well as successful clinical implementation, it is important to be clear about how and when each outcome evaluation tool is used as part of the guideline. For this reason, a summary of this has been provided in Figure 2 for children with aided hearing loss. The figure summarizes the administration of each outcome evaluation tool within the UWO PedAMP during a child’s routine follow-up.

| | Appointment Type (Aided) | | | | | | | |
|-----------------------------|---------------------------------------------------------------------|-----------|-----------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|--------------|
| | Initial Assessment | Profiling | Initial Fitting | 30 Day Recheck | 3 month Rechecks | 6 month Rechecks | Yearly Rechecks | Event Driven |
| Hearing Aid Fitting Details | X | X | ✓ | X | ✓ | ✓ | ✓ | ✓ |
| HP Hearing Aid Benefit | X | X | X | X | ✓ | ✓ | ✓ | ✓ |
| LittEARS | Establish Unaided Baseline: Administer at one of these appointments | | | Worn 12T, Use LittEARS, use PEACH | Worn 12T, Use LittEARS, use PEACH | Worn 12T, Use LittEARS, use PEACH | Worn 12T, Use LittEARS, use PEACH | ✓ |
| PEACH | X | X | X | ↓ | ↓ | ↓ | ↓ | ✓ |

Figure 2. Administration guidelines for children with PCHI who wear hearing aids. The top row specifies the appointment type and the far left column indicates the outcome evaluation tool within the UWO PedAMP that should be administered. Within the grid, ‘✓’ and ‘X’ designates when an outcome evaluation tool should or should not be administered at a particular appointment.

Each outcome evaluation tool within the UWO PedAMP is listed down the left-hand side of the figure. The clinician can determine whether a tool should (‘✓’)

or should not (‘X’) be administered during a specific appointment that is listed across the top of the figure. It should be noted that each tool within the UWO PedAMP is being administered during a routine clinical appointment. Extra appointments are not necessary to complete the UWO PedAMP; however some extra clinical time may be needed for completion (i.e., up to 20 minutes).

The OIHP Amplification Benefit Questionnaire

The OIHP Amplification Benefit Questionnaire is an eleven-item questionnaire that was developed jointly by the OIHP and the members of the Child Amplification Laboratory at the University of Western Ontario (see Bagatto, Moodie and Scollie 2010). Using a five-point rating scale, this tool addresses acceptance and use of hearing aids, auditory performance for different levels of sound, effectiveness of service delivery and overall satisfaction. The final question is open-ended and asks the caregiver about how hearing aid services could be improved within the OIHP. It is recommended that the questionnaire be answered by the caregiver after their child has worn hearing aids for *three months or more* so as to give the caregiver a chance to become accustomed to and comfortable with their child’s hearing aids and the services offered by the EDHI program. It should be readministered at follow-up visits thereafter (see Figure 2). The questionnaire takes a few minutes to complete. A summary of responses for this tool from 48 caregivers of children (mean age = 38 months; age range = 6.9 to 85.1 months) with aided PCHI (75 administrations) are provided in the Figure 3.

The questionnaire informs the program about how many hours per day the child wears the hearing aid(s) (Figure 3a) and as more data are collected, norms for usage as a function of age and hearing level may be obtained. With this sample, roughly 54% of the children wear their hearing aid(s) more than 8 hours per day, according to the respondent of the questionnaire. The questionnaire also elicits information about responsiveness to sound with 49.3% responding to average level sounds ‘Most of the Time’ (Figure 3b) and 58.7% ‘Never’ or ‘Rarely’ showing discomfort to loud sounds (Figure 3c). What is also interesting to gather from the OIHP Amplification Benefit Questionnaire is the caregiver’s report on their satisfaction of the hearing aid services for their child. In this sample, 93.3% indicated that they were ‘Most of the Time’ or ‘Always’ satisfied with the hearing aid services from the OIHP (Figure 3d). Open-ended comments about the program were usually favor-

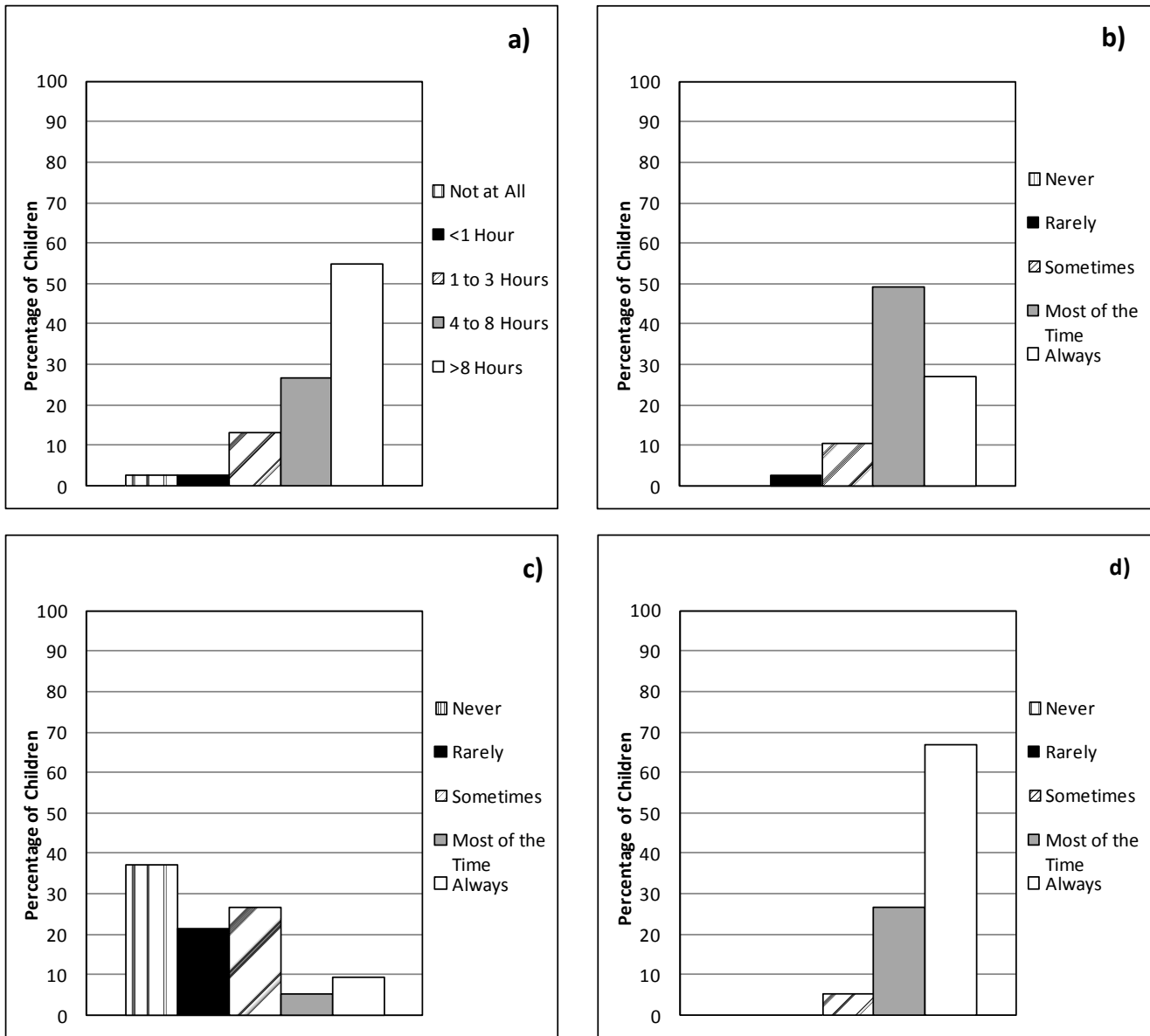


Figure 3. Preliminary data from select questions on the OIHP Amplification Benefit Questionnaire: a) daily hours of hearing aid use; b) response to average level sounds; c) discomfort to loud sounds; and d) overall satisfaction with hearing aid services. Caregivers responded to the questionnaire after at least three months of hearing aid use. Results are shown as a percentage of caregiver responses for each rating.

able or had to do with another aspect of the OIHP (e.g., funding programs for hearing aids that are external to the OIHP).

The OIHP Amplification Benefit Questionnaire is the only tool in the UWO PedAMP that addresses caregiver satisfaction with the hearing aid services they are receiving for their child. Program evaluation is a key aspect of obtaining continued funding, and often programs

are evaluated by how early the child is fitted with amplification (Joint Committee on Infant Hearing [JCIH] 2007). Caregiver satisfaction may be considered another important aspect of overall EHDI program quality and is evaluated by the OIHP Amplification Benefit Questionnaire. In addition, the child’s hearing aid use and satisfaction are addressed with this questionnaire, and there is no other tool in this guideline that addresses these topics.

Hearing Aid Fitting Details

Hearing aids are used or worn for a trial period by the majority of children who have been identified with PCHI. Evidence-based pediatric hearing aid fitting protocols are followed in order to ensure that an infant's hearing aid will positively impact the ability to develop auditory skills in daily life (e.g., AAA 2003; MCHAS 2005; BCEHP 2006; Bagatto, Scollie et al. 2010). Outcome evaluation is designed to be completed following the hearing aid verification stage of the fitting process as it allows one to measure the impact of the fitting. Since positive outcomes infer good hearing aid fittings, it is important to monitor factors associated with 'typical' hearing aid fittings as part of the UWO PedAMP. There are two primary reasons to monitor hearing aid fitting details. First, each clinician can determine whether an *individual child's fitting* is providing a typical degree of audibility. For example, if the output of the hearing aid is significantly less than the Desired Sensation Level (DSL[®]) v5.0a prescription, the child's ability to use sound for development may be impacted more than for a child with a typical DSL fitting. Clinicians and caregivers will have a better understanding of how the child is progressing with respect to audiological outcomes when details of the hearing aid fitting are tracked as part of an overall outcome evaluation guideline.

The second reason for monitoring hearing aid fitting details is *at the level of the program* as a whole. The brief fitting details gathered in this protocol will help to determine, for example, the typical rate at which real-ear-to-coupler difference (RECD) measures are made, or the typical amount of audibility provided by the hearing aid(s). Health care programs that receive government funding are increasingly being pressured to document that the services are of high quality. As part of the UWO PedAMP, two tools have been provided to monitor hearing aid fitting details and include: 1) the Hearing Aid Fitting Summary; and 2) Aided SII Normative Values. Used together, they provide helpful information for the audiologist, caregivers, and health policy-makers about the hearing aid fitting as part of this outcome evaluation guideline.

Hearing Aid Fitting Summary

The UWO PedAMP assumes that the audiologist has followed preferred practice guidelines for pediatric hearing assessment and the fitting of hearing aids to infants and young children (JCIH 2007). Once hearing aids have been obtained, simulated (or predicted) real-

ear measurements of hearing aid performance are the preferred method of verification for infants and young children and are recommended by several pediatric hearing aid fitting protocols (i.e., AAA 2003; MCHAS 2005; BCEHP 2006; Bagatto, Scollie et al. 2010). The real-ear performance of the hearing aid is predicted from coupler measures of speech inputs using the infant's RECD (Seewald, Moodie, Sinclair and Scollie 1999). The hearing aid's maximum power output (MPO) is verified using narrowband stimuli. Functional outcome evaluation of the hearing aid fitting will be measured through the use of questionnaires within the UWO PedAMP. In this guideline, the aim is to minimize the time needed to capture the hearing aid fitting details. For this reason, the exact fit-to-targets at each frequency and test level are not documented. Instead, the fit-to-targets are assessed by the clinician and the overall amount of audibility provided for low and moderate level speech (via the Speech Intelligibility Index [SII]) and whether or not key protocol elements were measured for each fitting (RECD, MPO) are monitored. A completed Hearing Aid Fitting Summary includes details about the RECD (Measured, Predicted, Used other ear values, Previously measured) and the MPO as well as SII values for soft and average speech inputs (zero to 100).

Aided Speech Intelligibility Index (SII) Normative Values

The SII is a value representing the proportion of speech that is heard by the listener through the hearing aids (American National Standards Institute [ANSI] S3.5 1997). It is an acoustic measure, not a behavioral prediction. This means that the SII represents the audibility of speech, and is not a prediction of speech recognition scores. The SII provides a value that clinicians, caregivers, and teachers can use to conceptualize the proportion of speech that is available to the child. SII values are provided from hearing aid verification systems (e.g., Audioscan Verifit[®], Interacoustics Affinity[®]) for various speech inputs. If a clinician has performed multi-level speech-based real-ear verification of the young child's hearing aids, the associated SII values for these measurements would also be provided.

Recently, normative data relating the specific SII values for acceptable hearing aid fittings became available (Moodie 2009, 2010). These were derived from pediatric fit-to-target data from 161 ears. From these data, the SII values were extracted to develop norms by pure-tone average (PTA) for use in the UWO PedAMP

(see Figure 4). It can be seen that a general pattern emerges in which the SII values decrease as hearing level increases. This trend is due to the application of the level distortion factor associated with the SII calculation and narrower bandwidth typical of higher gain fittings (ANSI S3.5 1997). What is also notable is the relatively few data in the severe to profound PTA range. Due to the lack of data in the region with higher PTA, a guideline for SII values is not provided at this time.

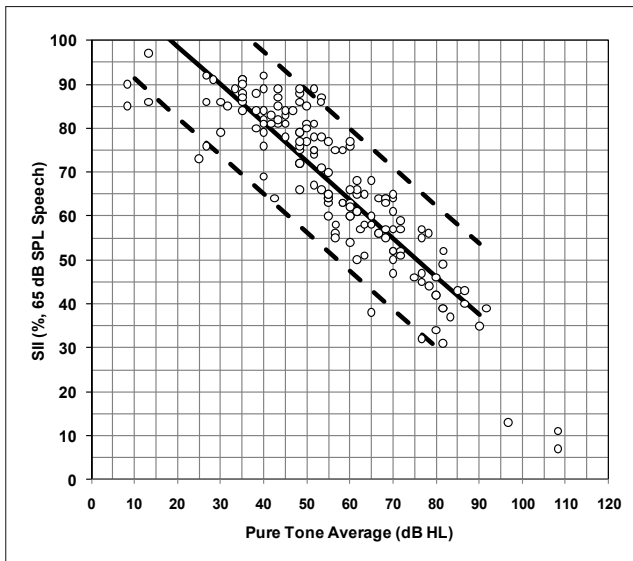


Figure 4. Aided SII Normative Data displaying SII values for a 65 dB speech input for a wide range of hearing losses. The SII values were obtained from hearing aid fittings on 161 ears of infants and children. The open circles represent individual SII values for a given pure tone average. The solid line represents the linear fit to the data and the dashed lines represent the upper and lower 95% confidence interval ranges. An SII value that falls between the dashed lines is considered to be a typical value for that pure tone average.

The fit-to-target work has revealed that the SII is not highly sensitive to minor or medium deviations from target. But it is sensitive to large, for example 20 dB, deviations from target. Given that the SII is already calculated in some real-ear systems, these norms allow the clinician to make use of the SII by PTA, and it can be useful for counseling purposes. The clinician's judgment is the most important way to determine an acceptable hearing aid fitting. The SII norms provide a gross index to supplement the clinician's judgment of fit-to-targets and are an overall indicator of the fitting's audibility. So, it is important for the clinician to assess the exact fit-to-targets data prior to assessing whether or not the SII is typical for a child's hearing level. If an SII value falls within

the dashed lines in Figure 4, it is considered typical for that PTA hearing loss. Tracking this clinical process outcome is important for interpreting scores on the functional outcomes such as the LittleEARS and the PEACH.

The LittleEARS Auditory Questionnaire

Background Information

According to the authors, the purpose of the LittleEARS Auditory Questionnaire is to assess the auditory behavior of infants with PCHI who wear hearing aids or cochlear implants (Tsaikpini et al. 2004; Coninx et al. 2009). The 35 items in the LittleEARS questionnaire assess auditory development during the first two years of hearing in the real-world and tap into receptive and semantic auditory behavior as well as expressive-vocal behavior. The questions are listed in an age-dependent order and are in a yes/no format. The total of all 'yes' answers provides a score that can be compared to average and minimum age-dependent values. These values are provided in one-month age categories based on normative data (Coninx et al. 2009). This questionnaire has been validated with German-speaking families and has been shown to have good reliability, internal consistency and predictive accuracy (Coninx et al. 2009). Normative values have been derived from German-speaking caregivers of children with normal hearing (Kuehn-Inacker, Weichbold, Tsiakpini, Coninx and D'Haese 2003), and the tool has been validated in 15 different languages from normal hearing infants and toddlers up to 24 months of age (Coninx et al. 2009). Regression curves for each language were essentially equivalent to the German-derived norm curve.

Evaluation of the LittleEARS Auditory Questionnaire

The LittleEARS was administered 449 times to 327 caregivers of children (mean age = 14.6 months; age range = 1.3 to 48.0 months) with various audiometric and medical profiles (i.e., normal hearing, aided PCHI, unaided PCHI, unaided auditory neuropathy spectrum disorder). Approximately 48% of the total sample were born prematurely (i.e., 37 weeks gestational age relative to a 40 week term) and 29% had other medical issues besides PCHI. This information was part of a larger data collection initiative and provides preliminary data to characterize various pediatric audiology populations.

The LittleEARS was developed for infants in their first two years of life, however, the recent work with this questionnaire has revealed that it is also suitable for children older than 2 years of age who may have been premature, who present with atypical development, or who are in the early stages of hearing aid use. Therefore, the original score sheet was revised to include a wider age range of use with children up to 48 months of age (see Figure 5). The total 'yes' score is entered on the score sheet at the point where age and score meet. A child with a score in the shaded region is considered to be not meeting age-appropriate auditory milestones. A child with a score above the shaded region is considered to be meeting age-appropriate auditory development milestones. The following section describes preliminary LittleEARS results from normal hearing children and those with aided PCHI.

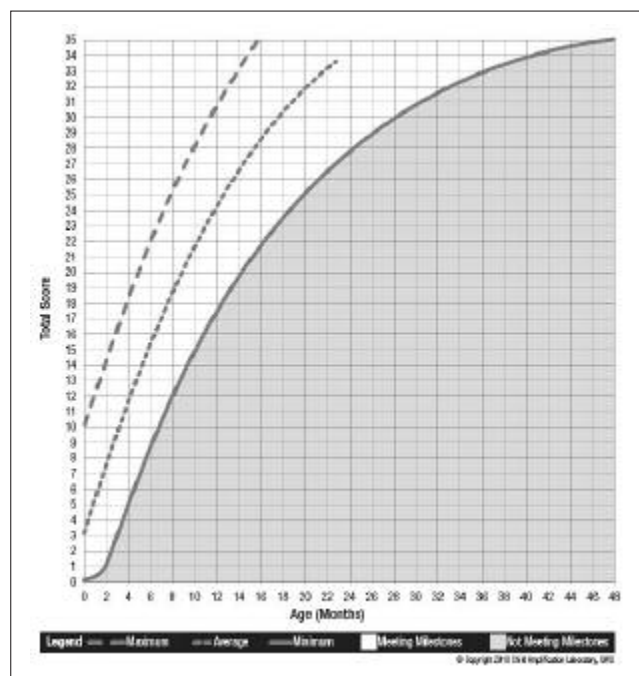


Figure 5. The LittleEARS Auditory Questionnaire modified score sheet where scores (y-axis) are plotted by age in months (x-axis) based on caregiver responses. The score is then compared to the German-derived norms (small dashed line) and the maximum (large dashed line) and minimum (solid line) expected scores. A child with a score falling within the non-shaded region is considered to be meeting age-appropriate auditory development milestones. A child with a score in the shaded region is not meeting age-appropriate auditory development milestones.

LittleEARS Results from Children with Normal Hearing

Of the total participant sample, 207 caregivers of children with normal hearing (mean age = 10.3 months; age range = 1.3 to 44.6 months) were administered the LittleEARS a total of 257 times. Within this group, 52.2% were premature and 7.3% had significant medical issues that may affect their development. The LittleEARS scores for typically developing children who were born full term indicated that 88.4% were meeting auditory development milestones for their age (Figure 6). Seventy-five percent of normal hearing children who were born prematurely and 46.7% of the children with medical issues were meeting auditory development milestones for their age (Figure 6).

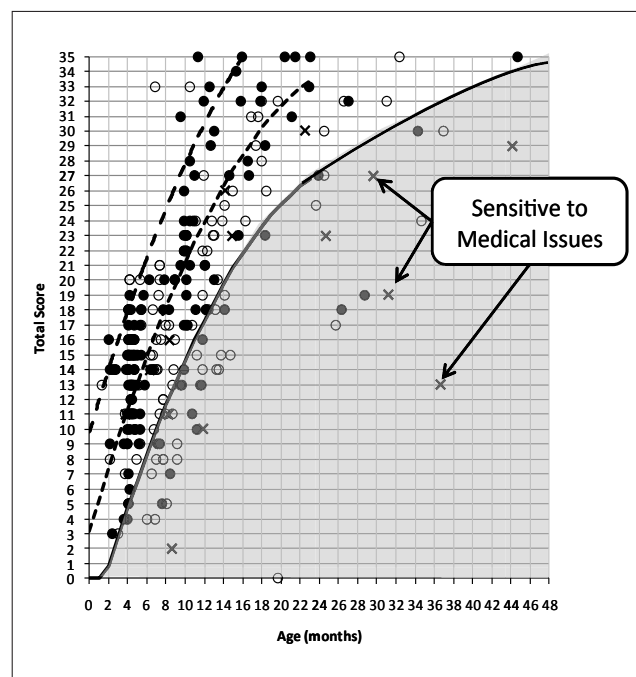


Figure 6. LittleEARS scores from a clinical population of normal hearing children. The solid line indicates the minimum expected score, the small dashed line indicates the average expected score and the large dashed line indicates the maximum expected score from the German-derived norms. Filled circles indicate typically-developing children, open circles indicate children who were born prematurely (37 weeks gestational age or earlier relative to a 40 week term), 'X's indicate children with other medical issues. Children with scores in the non-shaded region are considered to be meeting auditory development milestones for their age and children with scores in the shaded region are considered to be not meeting milestones. Scores from children born prematurely have been plotted using their chronological age.

These results indicate that the majority of children in this normal hearing sample that are typically developing, as well as those born prematurely, display development of auditory skills in a manner that is reflected by the norms for the LittEARS questionnaire. For children with medical issues, more data are needed to further characterize their auditory development. However, as illustrated in the figure, the LittEARS questionnaire is sensitive to medical issues affecting auditory development, as shown by scores in the shaded region for these children. A better understanding of the developmental trajectory of auditory behaviors for these children will allow the clinician to have the tools to interpret scores for children who are not typically developing rather than comparing their scores to children who are. This will also provide the caregivers who complete the questionnaire a way to track their child's auditory development and not feel discouraged that the scores are being compared to 'normal.' Overall, the majority of the normal hearing children displayed auditory development appropriate for their age according to the LittEARS auditory questionnaire.

LittEARS Results from Children with Aided Hearing Loss

Of the total sample of children involved in the ongoing evaluation of LittEARS, 34 caregivers of children (mean age = 27.3 months; age range = 6.9 to 48.0 months) with aided PCHI were administered the questionnaire a total of 50 times. All hearing aids were fitted according to the OIHP amplification protocol (Bagatto, Scollie et al. 2010) and hearing losses ranged from mild to profound, unilateral or bilateral sensorineural. Many of the children were identified as having other medical issues (52.9%) and complex factors (64.7%; e.g., inconsistent hearing aid use, recurrent middle ear dysfunction). This demonstrates the heterogeneity of the pediatric population with aided PCHI. One future goal of this work is to characterize these data by degree of hearing loss; however, further data collection is required before this can be accomplished. A preliminary look at the overall data for children with aided PCHI indicates approximately 60% of LittEARS scores were within the typical auditory development range (Figure 7). A closer look at typically developing children with aided PCHI indicates that approximately half of them (53.8%; $n = 7$) are meeting auditory development milestones for their age. As previously noted, many of the children with PCHI assessed with the LittEARS display other medical issues

or complex factors that may impact on their auditory development and outcome with hearing aids. Children born prematurely in this sample are meeting auditory development milestones in 71.4% of cases ($n = 10$) and children with comorbidities are meeting milestones 14.3% of the time ($n = 1$). Finally, children with complex factors related to hearing aid use are meeting auditory development milestones in 75.0% of cases ($n = 12$). The sample size for each subgroup is small, but data collection is ongoing and more data for each group will be collected as the work continues.

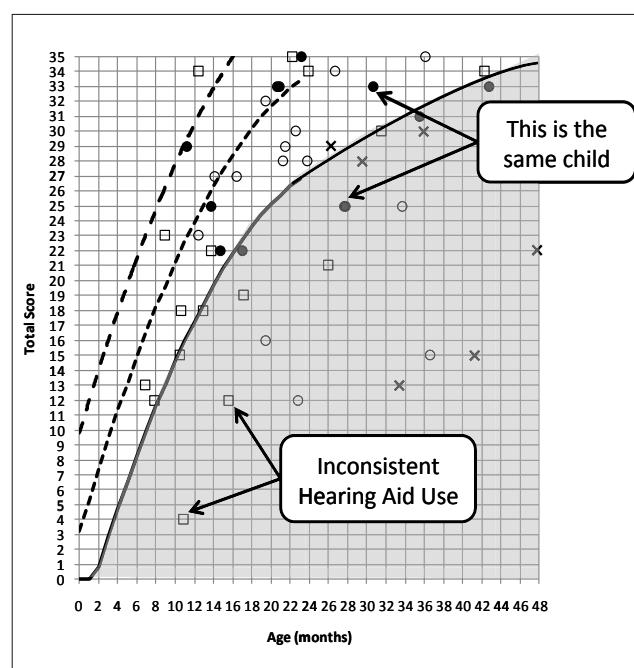


Figure 7. LittEARS scores from children with aided PCHI. The solid line indicates the minimum expected score, the small dashed line indicates the average expected score and the large dashed line indicates the maximum expected score from the German-derived norms. Filled circles indicate typically-developing children, open circles indicate children who were born prematurely (37 weeks gestational age or earlier relative to a 40 week term), 'X's indicate children with other medical issues, and squares indicate children with multiple factors. Children with scores in the non-shaded region are considered to be meeting auditory development milestones for their age and children with scores in the shaded region are considered to be not meeting milestones. Scores from children born prematurely have been plotted using their chronological age. Two individual cases have been flagged to illustrate key aspects of repeated administrations. See text for details.

Close examination of an individual case may provide an indication of the sensitivity of the LittEARS questionnaire for children with aided PCHI. As seen in the figure, a 27 month old child who was late-identified with a severely-sloping mild to profound sensorineural hearing

loss in both ears demonstrated an initial aided LittEARS score that revealed the child was not meeting auditory development milestones. With three months of experience with hearing aids that had typical SII values for her degree of hearing loss, the aided LittEARS score improved and indicated the child was meeting auditory development milestones at 30 months of age (see Figure 7, case labeled “This is the same child”). This supports the use of this tool beyond the recommended 24 month age cut off, and the use of repeated administrations to track the change in auditory development over time.

While this tool is sensitive to the positive impact of an appropriate hearing aid fitting, the LittEARS has also demonstrated sensitivity to inconsistent hearing aid use for a typically-developing child with a profound hearing loss (see Figure 7, case labeled “Inconsistent hearing aid use”). This particular child reportedly wore his hearing aids approximately one hour per day. Although the SII values were typical for his degree of hearing loss, his reported LittEARS scores indicated he was not meeting auditory development milestones at 10 and 16 months of age. Using this information during counseling sessions with the caregiver will hopefully support the need for increased wearing time of the hearing aids on a daily basis.

Summary and Future Work

The LittEARS auditory questionnaire is a short questionnaire that caregivers and clinicians find feasible to complete clinically. The questionnaire has been shown to be sensitive to other medical issues besides hearing loss. Further LittEARS data collection with children who have aided PCHI will facilitate the characterization of scores for infants and children with various audiometric and medical profiles for application in a clinical context. For example, when a score is obtained for a child with aided severe PCHI the clinician will be able to relate that score to data collected from a group of typically developing children with the same aided degree of hearing loss. On the other hand, many of the children in this initial data set have other medical issues or complex factors and these children may be characterized differently. Overall, this information will add great value to the application and interpretation of the LittEARS in future versions of the UWO PedAMP.

Through this work, the LittEARS has been shown to be useful for monitoring the progression of auditory development in infants and young children who have normal hearing and aided PCHI. As part of version 1.0 of

the UWO PedAMP, the LittEARS can be used for children from birth to approximately 48 months of age, depending on their score on the tool. A close look at the items on the LittEARS and the PEACH, which has items more appropriate for older children, indicate a stopping rule was needed to make the application of these tools feasible to utilize in a clinical population. Therefore, when a minimum score of 27 or better is achieved on the LittEARS, the child’s performance is considered to be at a ceiling score. If ceiling is reached, the tool should no longer be administered. Instead, the clinician can begin to administer the Parent’s Evaluation of Aural/Oral Performance in Children (PEACH), either at that appointment or at the next follow-up visit. Children who are younger than 24 months of age and achieve the ceiling score on the LittEARS may not yet be in the developmental range of the PEACH. The clinician may want to continue to administer the LittEARS until the child is 24 months of age, or interpret low scores on the PEACH knowing the child may not yet be within the developmental range of the tool. This age-criterion will be revisited as further data for both tools are collected and analyzed.

Parents’ Evaluation of Aural/Oral Performance in Children (PEACH)

Background Information

The Parents’ Evaluation of Aural/Oral Performance in Children (PEACH) is included as a subjective outcome evaluation tool in the UWO PedAMP v1.0. The PEACH in its original diary form is conducted using a structured interview format and has questions that address quiet and noisy situations, as well as hearing device and telephone usage (Ching and Hill 2005b). The PEACH Diary requires caregivers to observe their child for at least one week and record their observations for the 13 scenarios over that time period. They are also asked to rate the frequency of each behavior and provide examples of when the child did or did not exhibit a particular response. After the observation period, the audiologist meets with the caregiver to address each item in a face-to-face interview. The interview is structured in order to solicit detailed information from the caregiver, rather than yes/no answers. The creators of the PEACH have evaluated it over the past few years. The diary was administered to 90 caregivers of normal hearing children and 90 caregivers of children with aided PCHI to obtain normative data. The tool demonstrated good in-

ternal consistency (Cronbach's $\alpha = 0.88$) and high test-retest reliability ($r = 0.93$). Normal hearing children (age range = 0.25 to 46 months) demonstrated an increase in performance from about 6 months of age and close to perfect performance (i.e., 90%) was achieved by about 3 years of age. As hearing loss increased, a decrease in performance was noted in children with hearing impairment (age range = 4 months to 19 years). Descriptive statistics for the PEACH were also reported indicating an overall test mean of approximately 62%, with similar mean scores for the quiet and noise subscales. The authors noted that the children with hearing impairment were late-identified, and the functional performance of children who are early-identified may be improved (Ching and Hill 2007). A follow-up study with children with severe-to-profound hearing loss demonstrated that the PEACH is sensitive to changes in frequency response slopes in hearing aids (Ching, Hill and Dillon 2008).

This observation and interview process required for the PEACH Diary was found to be heavy in administrative and respondent burden as reported in a research study (Golding et al. 2007) and through the Network of Pediatric Audiologists of Canada (Moodie 2010). A Rating Scale version of the PEACH (Ching and Hill 2005a) has been made available and includes most of the scenarios from the original PEACH Diary (Ching and Hill 2005b). The PEACH Rating Scale appears to be more acceptable to clinicians and caregivers because the respondent and administrative burden has been reduced (Moodie 2010). The PEACH Rating Scale has been selected for use in version 1.0 of the UWO PedAMP with children who have attained ceiling performance (i.e., total score of 27 or greater) on the LittleEARS Auditory Questionnaire. The instructions ask caregivers to recall their child's behavior in everyday life over the past week and rate their child's hearing performance across a range of hearing and communication scenarios. The nature of the rating scale allows it to be answered by the caregiver during an appointment with guidance from the clinician. The overall score is summed, along with summed scores for the quiet and noise subscales. Each sum (overall, quiet, noise) is converted to a percentage. An accompanying score sheet was developed as part of the UWO PedAMP and provides assistance with interpretation of individual scores (Figure 8).

Data collected from normal hearing children indicated that performance asymptotes around three years of age with a score of approximately 90% (Ching and Hill 2007). Mean overall performance for the hearing im-

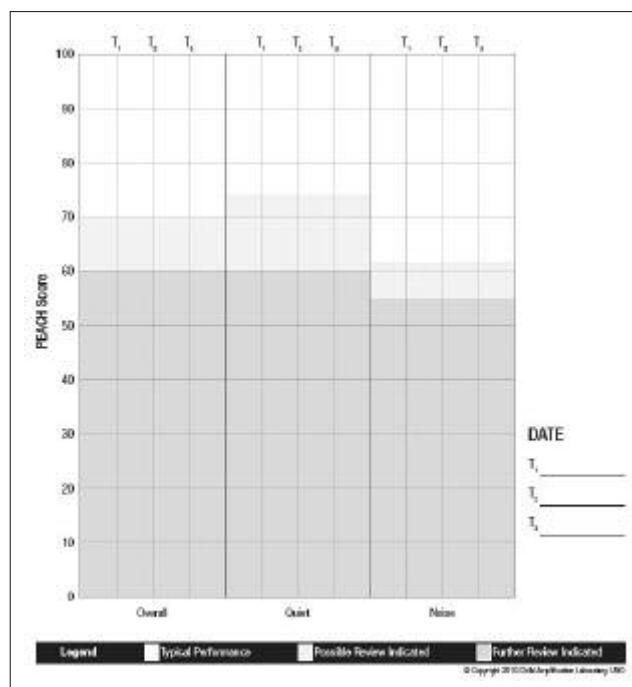


Figure 8. PEACH score sheet. Percentage scores (y-axis) for each subscale (x-axis) can be plotted for three different dates or conditions (T1, T2, T3). Scores in the non-shaded region indicate the child is demonstrating 'Typical Performance' with hearing aids. Scores in the lightly shaded region indicate 'Possible Review Indicated' and in the dark shaded region indicate 'Further Review Indicated'.

paired children involved in this study was 62% for both the quiet and noise subscales (Ching and Hill 2007). Hearing aid circuit type was not reported and may therefore have included linear hearing aid circuitry. Research conducted in the Child Amplification Laboratory at the University of Western Ontario in collaboration with the National Acoustics Laboratory (NAL) provided benchmarks for older hearing impaired children wearing WDRC hearing aids (Scollie et al. 2010). Many of these children were late-identified and caregivers answered the PEACH using a rating scale format. Overall PEACH scores for this collaborative work were roughly 80% and performance on the Quiet and Noise subscales were 84% and 72% respectively. These study results have been used as the basis for the PEACH score sheet within the UWO PedAMP and can assist with interpretation of individual scores. The unshaded and shaded regions can be used as benchmarks against which to interpret individual scores. Scores in the unshaded region indicate the child is demonstrating typical auditory performance. Scores in the light and dark shaded regions indicate that a possible review or further review is necessary

(see Figure 8). In future work, the performance ranges on the score sheet will be validated and the results will be incorporated into future versions of the UWO PedAMP as needed.

PEACH Results from Children with Aided Hearing Loss

Preliminary field work with the PEACH has demonstrated interesting clinical findings. Forty-five caregivers of children (mean age 45.3 months; age range 11.2 to 107.1 months) with aided PCHI were administered the PEACH a total of 75 times. Hearing losses ranged from mild to profound and were unilateral or bilateral sensorineural. Of the children involved, 26.7% were born 37 weeks gestational age or earlier relative to a 40 week term and 33.3% had other identified medical issues besides hearing loss. In addition, 62.2% of the children were noted to have a complex factor significant enough to potentially affect their outcome with amplifi-

cation. The remaining 23 children were typically developing and did not have complex factors related to amplification. The PEACH scores for these children are reported in Figure 9. The average overall score was 85.5% (SD = 10.31) and the quiet and noise subscales were 87.7% (SD = 11.49) and 82.6% (SD=11.95) respectively. This indicates that children who were identified and fitted early with high quality amplification and who are typically developing achieve high scores on the PEACH. In fact, the scores of children with aided PCHI in this sample are approaching the high score of 90% achieved by normal hearing children by age 3 years.

An example of a child born full term without complications with no reported family history of hearing loss demonstrated the sensitivity of the PEACH to good-quality intervention with hearing aids. This child was identified with a moderate to moderately-severe sensorineural hearing loss in the right ear and a moderate rising to mild sensorineural hearing loss in the left when she was 4 years old. The delay in identification was due to lack of caregiver follow-up. Hearing aids were fitted immediately and following a fit-to-targets evaluation, the SII values were compared to aided norms and shown to be typical for the child's puretone average.

Given the child's age at the time of the hearing aid fitting, her mother completed the PEACH and answered the questions for the child in the unaided condition. Scores ranged from 65%, 70%, and 60% for the Overall, Quiet and Noise subscales respectively (Figure 10). These scores fall within the 'Possible Review Indicated' area of the score sheet. After two months of experience with the hearing aids, the child's scores on the PEACH increased to 80%, 91%, and 65% for the same subscales. With five months of hearing aid experience, the child's scores improved to 88%, 91%, and 85% on the Overall, Quiet and Noise subscales respectively (Figure 10). These scores fall within the 'Typical Performance' area on the score sheet. An increase in the noise score may have coincided with the introduction of a light noise cancelling program as requested by the child due to her trouble listening while in the shopping center.

This demonstrates that the PEACH is sensitive to auditory performance in the unaided and aided condition and shows progression in scores with more experience with well-fitted hearing aids. The child's mother also completed the OIHP Amplification Benefit Questionnaire at each follow-up visit and consistently indicated that her child wears her hearing aids 'more than eight hours per day' and that she responds well to average and soft sounds 'most of the time.'

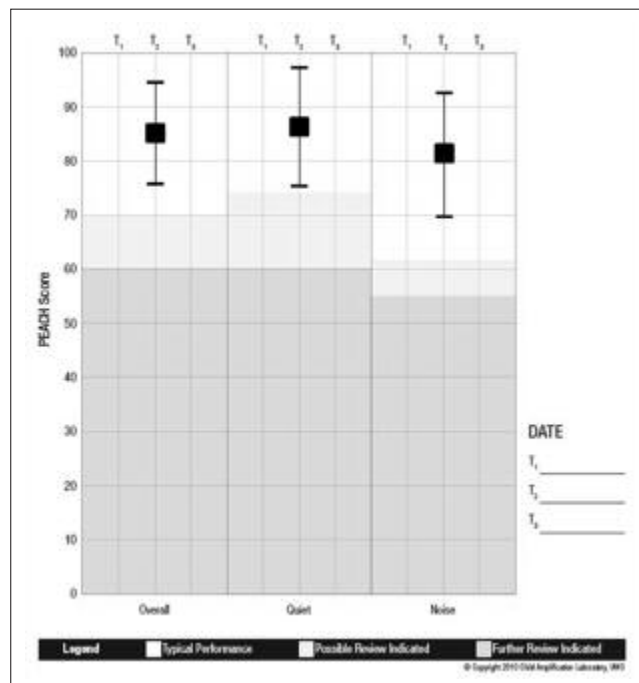


Figure 9. PEACH scores for 23 typically-developing, full-term children with aided PCHI. Squares represent average percentage scores for each subscale and vertical bars represent the standard deviation around the mean. Note that all scores are within the 'Typical Performance' (non-shaded) range for this sample of children.

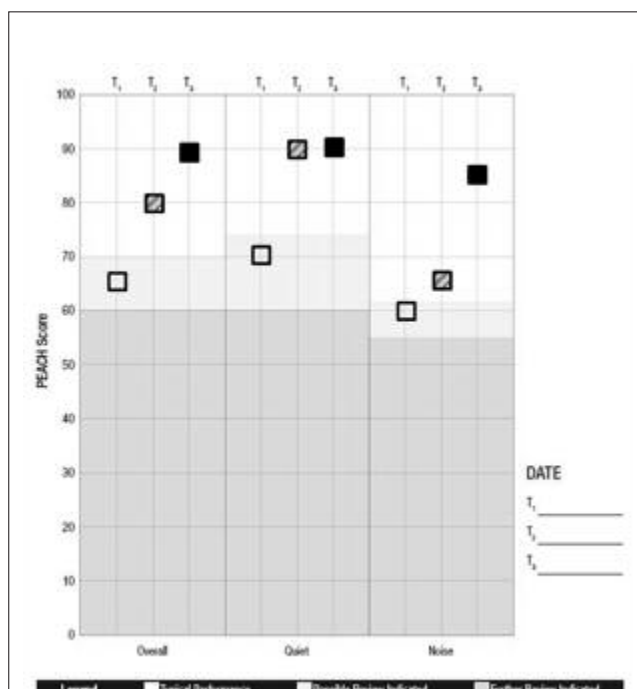


Figure 10. Case example of the PEACH. The PEACH percentage scores (y-axis) are plotted within each subscale (x-axis). Open squares indicate the unaided condition, hatched squares indicate two months of hearing aid use and filled squares indicate five months of hearing aid use. Results indicate that prior to the use of hearing aids, this child was demonstrating atypical auditory performance. As she gained experience with amplification she demonstrated an improvement in auditory performance over time in all subscales.

Summary and Future Work

Within the UWO PedAMP, the PEACH Rating Scale may be administered to children with hearing loss who wear hearing aids. A comparison of the LittEARS and the PEACH in terms of developmental range indicates that some items on the PEACH may not be within the developmental abilities of younger infants. Roughly 17 children with moderate to moderately-severe hearing impairment were younger than 50 months of age in the PEACH normative data (Ching and Hill 2007). Scores from these younger children and their normally hearing peers are lower, with normally hearing children reaching ceiling performance by 3 years of age. Although the PEACH appears to be sensitive to levels of hearing loss, its age-sensitivity may be due to the difficulty of items for younger infants or toddlers. Having the caregiver of a young infant complete the PEACH may be discouraging at the early stages as some questions may not be devel-

opmentally appropriate, making it seem as though the child is not performing well (i.e., respondent burden may be too high). Although the authors suggest certain modifications of items for use with young infants, the specific age range for modification is not known. *Therefore, administration of the PEACH should occur when the child has reached a score of 27 or greater on the LittEARS Auditory Questionnaire and at regularly scheduled follow-up visits thereafter, being cautious about interpreting scores for children less than 24 months of age (see Figure 1).* This pre-requisite should help to ensure that the child's auditory skills are more likely within the range of the PEACH.

The PEACH assesses functional auditory performance in quiet and noisy situations. Using the newly-developed score sheet, scores can be compared to scores derived from children with PCHI who wear hearing aids. This tool can assist in identifying whether a child is or is not performing typical auditory behaviors. For example, if the noise score is poor, options for listening comfort in noise (e.g., digital noise reduction) or for improving the signal-to-noise ratio (e.g., FM system) may be considered. Results to date indicate that the PEACH Rating Scale is appropriate for use within the UWO PedAMP with children who wear hearing aids after they have met a certain criterion on the LittEARS Questionnaire.

Conclusions

The UWO PedAMP v1.0 consists of several outcome evaluation tools that assess auditory development (LittEARS) and performance (PEACH) in children with aided PCHI. It also includes tools to track important hearing aid fitting details as well as an index of the appropriateness of the hearing aid fitting (SII) to assist with the interpretation of scores on the functional outcome questionnaires. Finally, this outcome evaluation guideline includes a tool that assesses overall service delivery and caregiver satisfaction with hearing aid services for their child. The OIHP Amplification Benefit Questionnaire provides a way to measure how an EHDI program is doing overall. The use of the KTA process framework and The Network of Pediatric Audiologists of Canada facilitated the development of the UWO PedAMP. The end result of this process is a guideline that is balanced in statistical properties as well as in clinical feasibility, utility and acceptability. The UWO PedAMP can be used in the final stage of the hearing aid fitting process where it facilitates the evaluation of the impact of the hearing fitting.

Outcome evaluation is an important stage of the pediatric hearing aid fitting process. Through the use of the UWO PedAMP, caregivers will become more involved in the process and will likely become good observers of their child's auditory behaviors. The systematic use of evidence-based questionnaires will foster a shared language between the caregiver and the professional (e.g., audiologist). Tracking and monitoring the child's auditory development and performance will become a routine and shared activity for the professionals and caregivers. The UWO PedAMP provides a systematic and evidence-based way of measuring the impact of the hearing aid fitting, which will hopefully improve the efficiency and effectiveness of service delivery. Finally, EHDI programs will have a way to measure how the program is doing, as well as to describe patterns that affect hearing impaired children within the program.

The UWO PedAMP is a guideline consisting of several outcome evaluation tools that aim to measure auditory-related outcomes in infants and young children. Access to visual tools to permit rapid scoring supports clinical feasibility and implementation on a regular basis. Preliminary data presented here help to support interpretation of scores obtained from the general clinical population, including those children with other medical issues besides PCHI and complex factors associated with hearing aid use. The UWO PedAMP will evolve through clinical implementation, and a continued community of practice is considered important for its success.

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