The Parents’ Evaluation of Aural/Oral Performance of Children (PEACH) Scale: Normative Data

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Abstract
The Parent’s Evaluation of Aural/Oral Performance of Children (PEACH) was developed to evaluate the effectiveness of amplification for infants and children with hearing impairment by a systematic use of parents’ observations. The PEACH was administered to 180 parents (one parent of each of 90 children with normal hearing that ranged in age from 0.25 to 46 months, and 90 children with hearing impairment that ranged in age from 4 months to 19 years). The internal consistency reliability was 0.88, and the test-retest correlation was 0.93. Normative data are presented to enable performance of children with hearing impairment to be related to their normally hearing peers and/or other children with similar degrees of hearing loss. Ninety and ninety-five percent critical differences are presented to facilitate evaluation of differences between scores obtained under different conditions for the same individual. The PEACH can be used with infants as young as one month old and with school-aged children who have hearing loss ranging from mild to profound degree.

Key Words: Amplification, children, functional evaluation, infants

Abbreviations: 3FA HL = three-frequency average hearing loss; PEACH = Parents’ Evaluation of Aural/Oral Performance of Children

Sumario
La Escala de Evaluación de los Padres sobre el Desempeño Auditivo/Oral Infantil (PEACH) fue desarrollada para evaluar la efectividad en la amplificación de infantes y niños con trastornos auditivos, haciendo uso sistemático de las observaciones de los padres. Se administró el PEACH a 180 padres (un progenitor por cada 90 niños con audición normal en edades entre 0.25 y 46 meses, y por cada 90 niños con hipoacusia en edades entre los 4 meses y los 19 años). La confiabilidad en la consistencia interna fue 0.88, y la correlación test-retest fue 0.93. Se presentan los datos normativos para establecer la relación entre niños con hipoacusia y niños normo oyentes, y/o con otros niños con grados similares de hipoacusia. Se presentan diferencias críticas del noventa y noventa y cinco por ciento para facilitar la evaluación de diferencias entre los puntajes obtenidos bajo diferentes condiciones en el mismo individuo. El PEACH puede utilizarse en niños desde un mes de edad hasta la edad escolar, con grados de hipoacusia de grado leve a profundo.

Palabras Clave: Amplificación, niños, evaluación funcional, infantes

Abreviaturas: 3FA HL = hipoacusia con promedio de tres frecuencias; PEACH = Escala de Evaluación de los Padres sobre el Desempeño Auditivo/Oral Infantil
The advent of newborn hearing screening has led to early diagnosis of hearing impairment, thereby making it possible to provide intervention to children with hearing impairment at a very early age. Although it is generally acknowledged that the provision of effective amplification is vital in aural rehabilitation, limited research is available on how to evaluate whether the amplification provided is effective in providing auditory information to children. Methods for systematic evaluation of amplification for school-aged children are available, such as paired-comparison judgments (Eisenberg and Levitt, 1991; Ching et al, 1999) and speech perceptual tests (Bess et al, 1996), but these methods are not applicable to infants and young children. Further, there is evidence to suggest that speech test results do not relate well to performance in real life (Vidas et al, 1992). Recent reports suggest that subjective scales based on reports of observations are valuable in assessing a child’s listening and communicative behavior (Crais, 1995; Osberger et al, 1997; Palmer and Mormer, 1999; Allum et al, 2000; Harrison, 2000; Young and Grohne, 2001). To date, a number of subjective scales are available (see Stelmachowicz, 1999; Arlinger, 2001), but most do not meet the needs for evaluating the effectiveness of amplification for young children.

General properties that apply to any evaluation measure have been discussed in Dillon et al (1999). A scale must assess what it purports to measure. If it is administered twice to the same person, then the difference in the results obtained must be small compared to the spread of scores observed among individuals or compared to the likely effect of some intervention on the attribute being measured. For the measure to be clinically useful, the time required for data collection and analysis must be commensurate with the value of the information obtained. Such information would be meaningful for the individual, for instance, if his or her scores may be related to those in a defined population and/or be used to assist in making informed decisions about rehabilitation strategies.

Additionally, several properties are desirable for measures intended for children because developmental issues are likely to influence performance. First, it is advantageous for a measure to be applicable to children over an extended age range. Longitudinal monitoring is often necessary to document outcomes of children because the time frame for changes in performance that can be attributable to amplification is likely to be longer for children than for an adult user of amplification. Applying the same measure over time would make it possible to track changes in auditory behavior as children mature. The subjective information would complement other objective measures when these could be used reliably. For an individual child, the time at which reliable objective testing is possible would be influenced by a range of factors including (but not limited to) age, cognitive development, and degree of hearing loss. Second, a measure that allows easy comparison of performance of children with hearing impairment to that of their peers with normal hearing makes it possible to separate the effects of normal development from that related to use of amplification. This may be achieved by expressing the performance of a child with hearing impairment in terms of standard deviations relative to performance of children with normal hearing of the same age. Third, it is desirable that the measure applies to children with a wide range of hearing losses rather than being limited to a specific degree of loss. Again, availability of normative data allows comparison of a child to his or her peers. It is useful, for instance, to tell a parent of a child with moderate hearing loss that the child is functioning within the range of his or her hearing-impaired peers rather than to say that the child is performing at a near-perfect level on a scale designed specifically for profoundly deaf children. Fourth, because a young child spends many of his or her waking hours outside an educational setting, it is useful to evaluate performance with amplification in a range of general everyday life situations. As a clinical tool, it must also be efficient and useful for habilitation. It is useful, for instance, to show that a child who has hearing impairment functions at a level that is below two standard deviations of the mean for children with normal hearing but at a level within the normal range after amplification is provided.


As shown in Table 1, information about test-retest reliability is available for only two measures, the children’s version of the Abbreviated Profile of Hearing Aid Performance (CA-PHAP; Kopun and Stelmachowicz, 1998) and the Hearing Performance Inventory for Children (HPIC; Kessler et al, 1990), and information about critical difference is available for only one

Table 1. Characteristics of Various Measures for Evaluating Listening Behavior of Children

<table>
<thead>
<tr>
<th>Measure</th>
<th>Respondent</th>
<th>Age (years)</th>
<th>Degree of hearing loss</th>
<th>Item no.</th>
<th>Setting</th>
<th>Normative data</th>
<th>Test-retest</th>
<th>Critical difference</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory Behavior in Everyday Life (ABEL)</td>
<td>Caregiver</td>
<td>4 to 14</td>
<td>Moderate to severe</td>
<td>38</td>
<td>General</td>
<td>Yes (n = 23)</td>
<td>-</td>
<td>-</td>
<td>Purdy et al, 2002</td>
</tr>
<tr>
<td>Children’s Abbreviated Profile of Hearing Aid Performance (CA-PHAP)</td>
<td>Child</td>
<td>&gt;10</td>
<td>Mild to severe</td>
<td>24</td>
<td>General</td>
<td>Yes (n = 50)</td>
<td>Yes (n = 10)</td>
<td>Yes</td>
<td>Kopun and Stelmachowicz, 1999</td>
</tr>
<tr>
<td>Client-Oriented Scale of Improvement—Child version (COSI-C)</td>
<td>Caregiver</td>
<td>&gt;0</td>
<td>All</td>
<td>5</td>
<td>General</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>K. Lovelock, pers. comm.</td>
</tr>
<tr>
<td>Children’s Home Inventory for Listening Difficulties (CHILD)</td>
<td>Caregiver</td>
<td>3 to 12</td>
<td>All</td>
<td>15</td>
<td>General</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Anderson and Smaldino, 1999</td>
</tr>
<tr>
<td>Developmental Index of Audition and Listening (DIAL)</td>
<td>Caregiver</td>
<td>&gt;0</td>
<td>All</td>
<td>17</td>
<td>General</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Palmer and Mormer, 1999</td>
</tr>
<tr>
<td>Functional Auditory Performance Indicators (FAPI)</td>
<td>Caregiver</td>
<td>&gt;0</td>
<td>All</td>
<td>7</td>
<td>General</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Stredler-Brown and DeConde Johnson, 2003</td>
</tr>
<tr>
<td>Hearing Performance Inventory for Children (HPIC)</td>
<td>Child</td>
<td>8 to 14</td>
<td>All</td>
<td>31</td>
<td>Education</td>
<td>-</td>
<td>Yes (n = 7)</td>
<td>-</td>
<td>Kessler et al, 1990</td>
</tr>
<tr>
<td>Listening Inventories for Education (LIFE)</td>
<td>Child</td>
<td>6 to 8</td>
<td>All</td>
<td>15</td>
<td>Education</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Anderson and Smaldino, 1999</td>
</tr>
<tr>
<td>Meanings Auditory Integration Scale (MAIS)</td>
<td>Caregiver</td>
<td>&gt;7.5</td>
<td>Profound</td>
<td>10</td>
<td>General</td>
<td>Yes (n = 50)</td>
<td>-</td>
<td>-</td>
<td>Robbins et al, 1991</td>
</tr>
<tr>
<td>Infant-toddler: Meaningful Auditory Integration Scale (TA-MAIS)</td>
<td>Caregiver</td>
<td>0.5 to 3</td>
<td>Profound</td>
<td>10</td>
<td>General</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Zimmerman-Phillips et al, 1997</td>
</tr>
<tr>
<td>Meaningful Use of Speech Sounds (MUSS)</td>
<td>Caregiver</td>
<td>Not known</td>
<td>Profound</td>
<td>10</td>
<td>General</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Robbins et al, 1998</td>
</tr>
<tr>
<td>Screening Instrument for Targeting Educational Risk in Preschool Children (Preschool SIFTER)</td>
<td>Teacher</td>
<td>3 to 5</td>
<td>All</td>
<td>Education</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Anderson and Matkin, 1996</td>
</tr>
<tr>
<td>Screening Instrument for Targeting Educational Risk (SIFTER)</td>
<td>Teacher</td>
<td>&gt;5</td>
<td>All</td>
<td>15</td>
<td>Education</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Anderson, 1989</td>
</tr>
</tbody>
</table>
measure, the CA-PHAP. Both the HPIC and the CA-PHAP are applicable only to children older than about eight years of age. The authors of the CA-PHAP acknowledged that children’s ratings might be confounded by their language comprehension ability (Kopun and Stelmachowicz, 1998).

Applying the age criterion reveals that only four scales may be used with children ranging from infants to older age groups. Three of these scales are based on individual goal setting: the child version of the Client-Oriented Scale of Improvement (COSI-C; K. Lovelock, pers. comm.; Dillon, 2001), the Developmental Index of Audition and Listening (DIAL) for use with the Family Expectation Worksheet and the Paediatric Hearing Demand, Ability and Need Profile (Palmer and Mormer, 1998), and the Functional Auditory Performance Indicators (FAPI; Stredler-Brown and DeConde Johnson, 2003). By using these scales, the clinician engages the parents to identify amplification goals for their own child and to review whether the goals have been achieved some time after amplification. The goals differ for children with different ages and different degrees of hearing loss. Whereas nonachievement of goals may warrant a review of the intervention (including amplification, implantation, and teaching strategies) provided, the scales do not directly estimate the effectiveness of intervention.

The fourth scale is the Meaningful Auditory Integration Scale (MAIS; Robbins et al, 1991) together with the infant-toddler version of the scale (IT-MAIS; Zimmerman-Phillips et al, 1998). This is a parent-report measure designed to be used for children with profound hearing loss. The scale comprises two items on “device bonding” and eight items on listening behavior and are administered to parents via an interview. The scale has high internal consistency (Weichbold et al, 2003), but test-retest information and critical differences have not been reported.

Of the four scales that apply to a wide age range for evaluating everyday life performance, only the MAIS has some normative data. Those data were obtained from children with profound hearing loss who were older than 7.5 years (Robbins et al, 1991). Because the scale was developed for children with profound hearing loss, the listening items reflect a relatively low level of auditory function, and ceiling effects were observed for children who were good users of hearing aids and children who received a cochlear implant within several months of implantation (Osberger et al, 1997; Allum et al, 2000). As reviewed above, none of the published scales fulfill the need for an evaluation tool that is suitable for children from infancy through school age, with hearing loss ranging from mild to profound degrees. The clinical application of some of the scales is also limited by the lack of test-retest data and critical difference score information.

The purpose of the present work was to develop a subjective measure that could be used to quantify the effectiveness of amplification for children in everyday life and that would cover children of a wide range of age and degree of hearing loss. This measure, which is called the Parent’s Evaluation of Aural/Oral Performance of Children (PEACH), relies on parents’ observations solicited in a structured interview based on a questionnaire. This paper reports normative data for the PEACH and the internal consistency, factor structure, test-retest reliability, and critical differences.

**METHOD**

**PEACH Scale**

The PEACH was developed as a measure of functional performance in everyday life, based on a systematic use of parents’ observations. It was recognized that parents spend much time with their children in a range of environments and would therefore be the best observers and informants of a child’s aural and oral abilities in daily life (Boudreau, 2005). Because the primary goal of amplification is to ensure audibility for a wide range of speech input levels and frequencies (Joint Committee on Infant Hearing, 2000; American Academy of Audiology, 2003), the items focused on aural/oral behaviors in speech communication situations in real life. Professionals including teachers of the deaf, early-intervention teachers, and audiologists contributed to the design of the items. To assist with audiological management, items about the routine of device usage and loudness comfort were included. To maximize the relevance of the items for each child, the PEACH contained items worded as topic areas. The items were printed in the form of a diary booklet in which written instructions were provided.
together with space under each item for parents to write down their observations (Appendix 1 shows an excerpt of one item. The complete PEACH booklet may be viewed on the NAL Web site: www.nal.gov.au). When the booklet was issued to the parents, they were asked to examine all items and identify times of the day and activities of their children that would provide information relevant to each item. Any uncertainty about the items was clarified. Parents were encouraged to carry the booklet with them at all times during an observation period of one week and to note down their child’s auditory behaviors in different situations with specific details about when and where the behavior occurred. They were asked to note down as many examples as possible and also to record situations when certain auditory behaviors did not occur.

In administering the PEACH to a parent, a habilitationist addressed each item in a face-to-face interview and wrote down all responses provided. An interview technique rather than a questioning technique was used in order to avoid “yes-no” responses and to increase the accuracy of the information obtained. This approach is similar to that used in other measures based on informants’ information such as the Vineland Adaptive Behavior Scales (Sparrow et al, 1984) and the MAIS (Robbins et al, 1991). For example, if information about a child’s alertness to environmental sounds is solicited, the habilitationist would obtain information by saying, “Tell me about the sounds that your child responds to,” and for each of the sounds named by the respondent, details about when and where the behavior was observed would be noted down. The parent would also be asked if he or she recalled situations in which the child did not respond to environmental sounds and, if so, to describe the situations in detail. Scoring was carried out by the habilitationist by using a five-point scale ranging from 0 to 4 (see Appendix 2 for a sample). The descriptive criteria for rating included the following: 0 = never or no examples were given; 1 = seldom or 25% of the time or one to two examples were provided; 2 = sometimes or 50% of the time or three to four examples were provided; 3 = often or 75% of the time or five to six examples were provided; and 4 = always or greater than 75% of the time or more than six examples were provided. The question on loudness comfort was reversed for scoring purpose so that a higher score reflected a better listening outcome for all sounds. The scoring took into account the number of examples provided by the respondent and the percentage of time that the child was reported to demonstrate a certain auditory behavior.

The initial version consisted of 20 questions and was administered to parents of ten school-aged children with hearing impairment. An observation period of one week was considered reasonable for obtaining a representative sample of the auditory behavior of a child in everyday life, and practical for parents to observe and record the behaviours in the PEACH booklet. At the interview, the habilitationist wrote down the observations of the parents and probed for further examples as much as possible. After the interview, the habilitationist scored the PEACH according to the scoring criteria described previously. Six items were eliminated because inspection of the data suggested that they were anomalous or confusing in some way. The remaining scale comprised 14 items, including two items on device usage (daily routine of use, awareness of device malfunction), one item on listening comfort (response to loud sounds), six items on listening to speech in relatively quiet situations (respond to name in quiet, respond to verbal instructions in quiet, follow a story read aloud, participate in conversations in quiet, recognize familiar voices, participate in conversation on a telephone), four items on listening to speech in situations that are noisy or when multiple talkers are present (respond to name in noise, respond to verbal instructions in noise, participate in conversations in noisy situations, participate in conversations in cars/buses/trains), and one item on awareness and recognition of environmental sounds.

The PEACH was designed to evaluate the effectiveness of amplification for children with no limitations placed on age or duration of hearing aid experience. Therefore, in evaluating the inventory, an effort was made to sample among children with hearing impairment with a wide range of age, hearing loss, and hearing aid experience. In order to assess the developmental appropriateness of the questionnaire and to collect normative data, a group of children who have normal hearing was also recruited.
Experiment 1: Internal Consistency

Subjects

Subjects comprised parents of 90 children with normal hearing and parents of 90 children with hearing impairment. One parent of each child participated in completing the PEACH booklet and attending the interview. The children with normal hearing ranged in age from 0.25 to 46 months (mean = 13.4 months, SD = 11.4 months). Their hearing status was ascertained by either a pass at newborn hearing screening or a pass in visual reinforcement audiometry. None of the children with normal hearing had any known history of ear or hearing problems. Figure 1 shows the distribution of the age of the children.

The children with hearing impairment ranged in age from 4 months to 19.75 years of age (mean = 95.6 months; SD = 64 months). The children had varying degrees of hearing loss ranging from mild to profound. Seven were unaided, two wore a hearing aid in one ear, 65 wore hearing aids in both ears, and 16 wore a hearing aid with a cochlear implant in opposite ears. Eight children were screened at birth and received their first hearing aids prior to six months of age. Children with known disabilities in addition to hearing loss were excluded.

Procedure

The parents were given a copy of the PEACH booklet and were asked to observe and record their child’s behavior in everyday situations that were relevant to each item over a one-week period. The administration and scoring methods were as described previously. Within a week of the observation period, the experimenter conducted a face-to-face interview with the parents. During the interview, the experimenter wrote down all examples provided for each item and probed for details regarding specific situations in which certain behaviors were or were not observed. Parents of children with hearing impairment were asked to supply information about their child’s routine of device usage and whether their child showed awareness when the devices did not function properly. These questions from the PEACH were not delivered to the parents of children with normal hearing. The interviews of parents of ten children with hearing impairment were recorded on audiocassette tapes, and a second scorer scored the questionnaire on the basis of the recorded interview.

Analysis

The developmental appropriateness of the questionnaire items was examined by relating the scores of children with normal

![Figure 1. The distribution of age of children with normal hearing.](image-url)
hearing to their age in months. The PEACH scores were arcsine transformed, and a logit function was fitted to the data by using a least squares procedure to minimize errors.

The completed questionnaires were analyzed to examine the internal consistency of the items by calculating Cronbach’s alpha. To examine the factor structure, data from all children were subjected to principal components analysis. Interscorer reliability was examined by calculating the correlation coefficient.

**Experiment 2: Test-Retest Reliability**

Because the PEACH questionnaire was designed for evaluation of amplification in individual subjects, it is useful to quantify the measurement error associated with a single administration of the questionnaire. An estimation of measurement error is required for the construction of critical differences that may be used to determine the significance of differences between scores of each individual in two or more conditions. If an obtained difference between two scores equals, for example, the 95% critical difference, it may be concluded with 95% certainty that there was a real difference between the two tested conditions. There would still be a 5% probability that the obtained difference occurred by chance.

**Subjects**

Subjects comprised of a subgroup of parents of children with normal hearing (n = 15) and children with hearing impairment (n = 17) who participated in the first experiment. The same parent of each child served as the observer for both experiments.

**Procedure**

The PEACH was administered a second time within two to four weeks of the first administration. The questionnaires were administered and scored in the same way as described previously.

**Analysis**

Repeatability was explored in two ways: via test-retest correlation coefficients and by constructing 90% and 95% critical difference values. Test-retest correlation coefficients can be viewed as providing information about the reliability of intersubject differences. Such correlations will be high if the ordering of individuals tends to remain constant across tests. The standard deviation of test-retest difference was used to estimate critical differences. The critical difference, in turn, can be used to evaluate the significance of difference between two scores from the same individual. The difference between two scores from the same person will exceed 95% critical difference by chance alone (i.e., when the real difference in scores is zero) on only 5% or less of comparisons. In clinical practice, critical differences can be used to evaluate difference between scores obtained under putatively different conditions (e.g., different hearing aid prescriptions). On the assumption that the measurement error in each of the two scores is independent, the standard deviation of the test-retest differences can also be used to infer the standard deviation of the measurement error in a single measurement.

**RESULTS**

**Experiment 1**

Of the 14 items in the questionnaire, the two items on device usage were applicable to only children with hearing impairment. The scores of the item on routine of usage indicated that 95% of children wore amplification devices most of the time (mean = 3.6; SD = 0.6; range = 2 to 4). Because the two items on device usage had very low item-total correlations (<0.2), they were removed in further analyses. About 88% of children, including those with normal hearing and those with hearing impairment, seldom or never showed signs of discomfort in response to loud sounds. These data suggest that children with hearing impairment did not experience more discomfort from loud sounds than normally hearing infants did, and an analysis of variance confirmed that there was no significant difference in the distribution of responses (F = 0.11, df = 1, p = 0.75). The item on loudness discomfort had very low item-total correlations in the analyses conducted separately for data of children with normal hearing (<0.1) and data of children with hearing impairment (<0.2). This item was therefore removed from further analyses. Because the same set of items
applied to data from children with normal hearing and children with hearing impairment, the data were combined for further reliability analysis. The standardized Cronbach’s alpha for the 11-item questionnaire was 0.88. Table 2 shows the 11 items and item-total correlations for the children.

The inter-rater reliability coefficient between the first and second scorer for the total scores was 0.95 (p < 0.001).

Principal component analysis with varimax rotation was used to investigate the factor structure of the 11-item PEACH questionnaire. A scree plot revealed that two factors had eigenvalues of greater than one, accounting for 59% of the total variance in scores. The first factor accounted for 38.5%, with three items having loadings greater than 0.8 (respond to instructions in quiet, respond to instructions in noise, and participate in conversation in transport) and five items having loadings between 0.5 and 0.69 (follow a story, participate in conversation in quiet, participate in conversation in noise, participate in conversation in transport, and recognize environmental sounds). The first factor was interpreted as “aural/oral communication.” The second factor accounted for an additional 19.5% of variance, with two items loading 0.8 (respond to name in quiet, respond to name in noise) and one item loading 0.5 (recognize familiar voices) on this factor. The factor is interpreted as “auditory awareness.” The factor loadings for all items are shown in the fourth and fifth columns in Table 2 under Factor Analysis I. The correlation between the scores for the first and second factors was 0.54 (p < 0.001), indicating that only 29% of the variability in scores on one scale can be attributed to the variability in scores on the other scale. These data suggest that the two factors accounted for aspects of performance that are related but different.

A second factor analysis was carried out to explore the feasibility of constructing subscales with the prospect of using them to evaluate advanced hearing aids that might perform differentially, within the same child, for favorable and adverse listening conditions. In this analysis, the 11 items were grouped according to the content of the item descriptors. The first group was labelled “Quiet,” comprising six items (respond to name in quiet, respond to verbal instructions in quiet, follow a story read aloud, participate in conversation in quiet, recognize voices, and participate in conversation on the phone). The second group was labelled “Noise,” comprising five items (respond to name in noise, respond to verbal instructions in noise, participate in conversation in noise, participate in conversation in transport, and recognize environmental sounds). Each group of items was subjected to item analysis and principal components analysis with varimax rotation.

For the Quiet group of items, the Cronbach’s alpha was 0.76. The scree plot revealed that only one factor had an eigenvalue of greater than one. This factor accounted for 46% of the total variance. Two items had loadings greater than 0.70 (follow instructions in quiet, follow story read aloud), and all other items had loadings greater than 0.50. For the Noise group of items, the Cronbach’s alpha was 0.79. The scree plot revealed that only one factor had an eigenvalue greater than one. This factor accounted for 57% of the total variance. Four

<table>
<thead>
<tr>
<th>Item no.</th>
<th>Description</th>
<th>Corr</th>
<th>Factor analysis I</th>
<th>Factor analysis II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Respond to name in quiet</td>
<td>0.41</td>
<td>0.13</td>
<td>0.81</td>
</tr>
<tr>
<td>2</td>
<td>Follow verbal instructions in quiet</td>
<td>0.76</td>
<td>0.88</td>
<td>0.11</td>
</tr>
<tr>
<td>3</td>
<td>Respond to name in noise</td>
<td>0.42</td>
<td>0.10</td>
<td>0.85</td>
</tr>
<tr>
<td>4</td>
<td>Follow verbal instructions in noise</td>
<td>0.77</td>
<td>0.83</td>
<td>0.19</td>
</tr>
<tr>
<td>5</td>
<td>Follow story read aloud</td>
<td>0.60</td>
<td>0.62</td>
<td>0.19</td>
</tr>
<tr>
<td>6</td>
<td>Participate in conversation in quiet</td>
<td>0.49</td>
<td>0.55</td>
<td>0.19</td>
</tr>
<tr>
<td>7</td>
<td>Participate in conversation in noise</td>
<td>0.65</td>
<td>0.57</td>
<td>0.49</td>
</tr>
<tr>
<td>8</td>
<td>Participate in conversation in transport</td>
<td>0.75</td>
<td>0.84</td>
<td>0.16</td>
</tr>
<tr>
<td>9</td>
<td>Recognize voice of familiar persons</td>
<td>0.54</td>
<td>0.43</td>
<td>0.52</td>
</tr>
<tr>
<td>10</td>
<td>Participate in conversation on phone</td>
<td>0.57</td>
<td>0.67</td>
<td>0.11</td>
</tr>
<tr>
<td>11</td>
<td>Recognize sounds in environment</td>
<td>0.63</td>
<td>0.62</td>
<td>0.32</td>
</tr>
</tbody>
</table>

Proportion of total variance explained: 0.39, 0.20, 0.45, 0.57
of the five items had loadings greater than 0.70 (follow instructions in noise, participate in conversation in noise, participate in conversation in transport, recognize environmental sounds), and the remaining item (respond to name in noise) loaded 0.55 on this factor. In Table 2, the final two columns show the factor analysis results. The correlation between the Quiet and Noise subscales was 0.85 (p < 0.001), which suggests that the two subscales account for aspects of behavior that are closely related.

The overall scores of the PEACH were recalculated from the 11 items. Figure 1 shows the PEACH scores of normally hearing children as a function of age. The logit function accounted for 82% of the total variance. The scores start to rise from a low plateau around six months of age and asymptote at near-perfect scores by about 40 months of age. The histogram of residuals revealed a normal distribution. Although visual inspection of the residuals showed slightly greater variability for infants who were under 20 months of age (n = 65) than those between 20 and 46 months (n = 25), the analysis of variance showed that the difference between age groups was not significant (F = 0.52, df = 1, p = 0.8). Accordingly, the standard deviation of all residuals was used to define confidence intervals. In Figure 2, the region bound by the broken lines shows ±2 standard deviations.

Figure 3 shows the overall PEACH scores of children with hearing impairment as a function of age, in relation to the normal curve. The children with hearing impairment were grouped according to the three-frequency average hearing loss (3FA HL 0.5, 1, 2 kHz) of their better ear into mild, moderate, severe, and profound degrees, as displayed in separate panels. Data from children who wore a hearing aid with a cochlear implant were presented as a separate category.

To quantify functional performance deficit for children with hearing loss, deviations of individual scores from the age-appropriate normal performance were computed. These age-corrected scores were related to the 3FA HL of the children. Figure 4 shows the increase in deficit (lower age-corrected scores) with increase in hearing loss. It is worth noting that profoundly deaf children who wore a cochlear implant and a hearing aid performed at levels that were equivalent to children with 3FA of 70 dB HL.

**Experiment 2**

Test and retest scores and test-retest differences for the overall score and subscale scores were computed for each subject. Table

![Figure 2](image-url)
Figure 3. PEACH scores of children with hearing impairment as a function of age for children with different degrees of hearing loss in relation to the normal curve of best fit. The dotted lines indicate extrapolations of the normal curve.

Figure 4. Age-corrected PEACH scores as a function of three-frequency average hearing threshold levels (3FA HL).
3 gives the mean scores and standard deviations as well as mean differences and standard deviations of the distributions of differences. The mean test-retest difference was small, ranging from 0.9 for the Quiet subscale to 1.7 for the Noise subscale.

A repeated measures ANOVA with time (test vs. retest) as a dependent variable and hearing status (NH vs. HI) as a categorical variable was performed. Results indicated that the main effect of time and the main effect of hearing status were not significant (p = 0.26 and p = 0.08, respectively) and the interaction was not significant (p = 0.93).

Correlation coefficients were computed between the test and retest scores for the overall scores (r = 0.93, p < 0.0001) and for the quiet and noise subscale scores (r = 0.81; r = 0.93; p < 0.0001). The correlation coefficients reflect both repeatability and the range of scores. The coefficients are indicative of the extent to which individuals who scored relatively low (or high) on one occasion also scored relatively low (or high) on a second occasion.

The 90% and 95% critical differences were computed using the standard deviation of test-retest differences between scores. The critical differences were 9.3% and 11% respectively. These critical differences may be used to evaluate the significance of difference between two scores from the same individual obtained under different conditions or from two individuals. If the difference between two scores exceeds the 90% critical difference, there is less than a 10% likelihood that this difference was due to chance. In view of the variability of individual data, a 90% critical difference might be considered sufficiently stringent in clinical applications, since it yields a likelihood of drawing correct conclusions nine out of ten times.

**DISCUSSION**

The outcome of the investigations described above was an 11-item questionnaire for assessing functional auditory performance in everyday life. The PEACH uses items that depict topic areas relevant to evaluation of amplification devices but offers flexibility for clinicians and parents to specify situations in a child’s daily life that are relevant to each item. The subjects for the two experiments were parents of children ranging in age between 0.25 months and 19.75 years. Children with hearing impairment had varying degrees of hearing loss ranging from mild to profound and included children who wore hearing aids as well as children who used a cochlear implant and a hearing aid in opposite ears. Thus, the PEACH appears to comprise items that are well suited for evaluation of functional auditory performance of children of a wide range of age and degree of hearing loss. With increasing recognition of the value of combining subjective assessments with objective clinical assessments when evaluating hearing aid or cochlear implant outcomes in children (Stelmachowicz, 1999; Harrison, 2000), the PEACH is another subjective assessment tool that complements other available tools in providing information about the functional auditory performance of infants and children.

The PEACH data on normally hearing children (aged 0.25–46 months) revealed an increase in performance from about six months of age to an asymptote at near-perfect scores by about three years of age. The performance of children who receive audiologic habilitation may be related to their normally hearing peers by using this normative curve. The data on children with hearing impairment (ranging in age from 4 months to 19.75 years) demonstrate a decrease in functional performance with increase in hearing loss. The hearing loss of a majority of these children was identified relatively late. It may reasonably be expected that with earlier intervention as a result of newborn hearing screening, the functional performance of children with amplification would improve (Yoshinaga-Itano, 2004). Future research will be needed to examine the

### Table 3. Mean Test and Retest Scores and Standard Deviations (SD) as well as Means and Standard Deviations (SD) of Test-Retest Differences for the PEACH

<table>
<thead>
<tr>
<th>Scale</th>
<th>Test mean</th>
<th>Test SD</th>
<th>Retest mean</th>
<th>Retest SD</th>
<th>Test-retest mean</th>
<th>Test-retest SD</th>
<th>90% CD</th>
<th>95% CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>62.9</td>
<td>14.9</td>
<td>64.2</td>
<td>12.9</td>
<td>-1.3</td>
<td>5.6</td>
<td>9.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Quiet</td>
<td>62.5</td>
<td>13.7</td>
<td>63.4</td>
<td>13.4</td>
<td>-0.9</td>
<td>8.4</td>
<td>13.9</td>
<td>16.5</td>
</tr>
<tr>
<td>Noise</td>
<td>63.3</td>
<td>18.8</td>
<td>65.0</td>
<td>16.1</td>
<td>-1.7</td>
<td>7.3</td>
<td>12.0</td>
<td>14.2</td>
</tr>
</tbody>
</table>

*Note:* The table also gives 90% and 95% critical difference (CD) values for overall score and subscale scores (n = 32).

The data on profoundly deaf children who used a cochlear implant and a hearing aid in opposite ears reveal that their performance was more similar to performance of children who were users of bilateral hearing aids with moderately severe hearing loss than those with profound loss (Figure 4). This is consistent with previous reports showing that word-recognition ability of profoundly deaf children with implants was equivalent to hearing aid users with 88 dB HL hearing loss (Boothroyd and Eran, 1994; Geers et al, 2003) and sentence perception of profoundly deaf children with implants was equivalent to hearing aid users with 78 dB HL hearing loss (Blamey et al, 2001).

The internal consistency of the PEACH is similar to corresponding data obtained using other parent-report tools with school-aged children (Purdy et al, 2002; Weichbold et al, 2003). In this study, two factor analyses were performed. The first analysis showed that the items fall into two factors, “auditory awareness” and “aural/oral function.” These factors are indicative of different levels of functional performance, which could be used to guide habilitation strategies for the development of specific skills. The second analysis was based on items grouped according to content into the “Quiet” and the “Noise” subscales. Within each group, reasonably high item-total correlations were obtained. This analysis has high relevance to evaluation of the effectiveness of amplification, because advanced devices (including hearing aids and cochlear implants) have different signal processing capabilities for different acoustic environments. Scores on the subscales could be used to evaluate whether a child functions effectively or otherwise in different acoustic environments, and could be used to indicate whether alternative devices/features/sound processing strategies need to be implemented for an individual child.

Although no previous studies have specifically addressed the critical differences of parent-report scales, studies on self-report measures for adults have produced comparable critical differences for subjective data from hearing-impaired persons. Weinstein et al (1986) reported a 95% critical difference of 36% for the pencil-and-paper version of the Hearing Handicap Inventory for the Elderly. Demorest and Erdman (1988) reported a 95% critical difference based on average test-retest standard deviations for the 25 scales of the CPHI to be 30% of the scoring range. Cox and Rivera (1992) reported 95% critical differences for the subscales of the Profile of Hearing Aid Benefit to be between 25 and 38%. The present data on PEACH indicate that, if data are to be evaluated on an individual basis, the changes in amplification would have to produce an 11 to 16.5% difference in functional performance score to be judged truly different at the 5% significance level. A difference of this size seems likely from aided to unaided but probably less likely from hearing aid fittings implementing two strategies. Furthermore, differences smaller than 16.5% would probably be important. A change of 16.5%, for example, is the equivalent of increasing a hearing loss from 50 dB 3FA HL to 80 dB 3FA HL (see Figure 4). In addition to the overall score, the two subscale scores would promote the diagnostic/clinical utility of the PEACH for capturing changes in auditory performance associated with alterations in amplification characteristics. The test-retest standard deviation is small (ranging from 5.6% to 8.4%) compared to the between-subject standard deviation of test scores (ranging from 12.9% to 18.8%), indicating that most of the scatter seen in Figures 3 and 4 is due to real differences between children rather than the effects of random measurement error. The test-retest differences reported in this study pertain only to the method of administration described in this study. As the time interval between the first and second administration of the tests was short (2 to 4 weeks), it is possible that parents quoted similar real-life examples during the interviews, thereby resulting in similar scores. The reported data on reliability should be regarded as preliminary, and additional studies of reliability particularly over longer time intervals are needed to refine the critical differences for the overall and subscale scores.

When functional performance is used to evaluate the efficacy of amplification of a child, it is important to ensure that amplification devices are consistently used during the observation period. The data from children with hearing impairment in this study revealed that 95% of the children used hearing aids at least half of their waking hours. If hearing aids are seldom used or not
used at all, the reasons underlying the lack of consistent usage will need to be investigated and resolved prior to evaluation of the effectiveness of the devices. The question on listening behavior in response to loud sounds is useful for identifying whether the maximum output of the hearing aids needs to be lowered and/or whether the compression ratio for medium- to high-level sounds needs to be increased. For these reasons, the PEACH includes two pre-interview questions: one that relates to usage and one to loudness discomfort (see Appendix 2). These questions do not contribute to the overall PEACH scores or subscale scores but help to uncover problems related to usage that need to be addressed prior to assessment of functional performance with amplification.

It is envisaged that clinical applications of the PEACH might include (a) comparing functional performance achieved by the same child under two hearing conditions that differ in terms of intervention (aided vs. unaided; cochlear implants vs. hearing aids), processing (e.g., gain-frequency response “A” vs. gain-frequency response “B”; or implant MAP “A” vs. MAP “B”), configurations (e.g., monaural vs. binaural), or other variables; (b) relating performance of an individual hearing-impaired child to a norm group (e.g., age-matched normally hearing children or children with similar degrees of hearing loss) for determining efficacy in a normative sense; and (c) using the overall and subscale scores to plan appropriate intervention (e.g., parental observations have been found to be especially useful for managing children with changing audiological patterns; see Skinner, 2006).

CONCLUSIONS

The PEACH scale has been developed to assess functional performance of children over a wide range of age with hearing loss ranging from mild to profound. It has the potential as a useful clinical tool for measuring the functional outcomes of infants and children who receive hearing aids and/or cochlear implants. Information about auditory behaviors in everyday life would complement other objective test results in a battery of assessments. Normative data are provided so that performance of an individual child can be compared with the mean performance of children with normal hearing and those with hearing impairment. Evaluation of the significance of difference between two administrations of the scale to the same individual (in a clinical application) can be accomplished through a consideration of the reported critical differences. Further studies are needed to examine the validity of the functional performance scores provided by the PEACH, and the sensitivity of the PEACH scale to differences in amplification strategies. It also will be necessary to accumulate experience with the scale through extensive use by interested parties before we can determine the full strengths and weaknesses of the scale and whether modifications, such as additional items, appear desirable.

Acknowledgments. We are very grateful to all parents and their children for participating in this study. We thank Alison Gangell and Louise Reynolds for their help in collecting some of the data reported in this paper. We also thank Harvey Dillon and two anonymous reviewers for providing useful comments on an earlier version of this paper.

REFERENCES


Appendix 1. Example of an Item in the PEACH Booklet

2. You are in a quiet place with your child (For example, he/she may be sitting next to you, behind you or across the room when the TV is off). When you ask him/her a simple question (For example, where’s Mummy?), or to do a simple task, (For example, look, clap, wave, point, pick up a toy, go and get your shoes etc) does he or she respond the first time you ask?

Quiet situations may be when the TV, music or radio is off or when any other people in the house are in another area or doing quiet activities.

Please list examples of when your child has or has not displayed the above behaviour over the last week, describing when and where they occurred.

__________________________________________________________________________________________________
__________________________________________________________________________________________________
__________________________________________________________________________________________________
__________________________________________________________________________________________________
__________________________________________________________________________________________________
__________________________________________________________________________________________________
__________________________________________________________________________________________________
__________________________________________________________________________________________________

Child's Name: ___________________________  D.O.B. ____________  Sex: ______

Respondent: _____________________________  Interpreter: ____________  Date: ______

<table>
<thead>
<tr>
<th>Frequency of reported behavior</th>
<th>Never</th>
<th>Seldom</th>
<th>Sometimes</th>
<th>Often</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-interview questions:</td>
<td>0%</td>
<td>25%</td>
<td>50%</td>
<td>75%</td>
<td>&gt;75%</td>
</tr>
<tr>
<td>Child's use of hearing aids/cochlear implants</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Is your child upset by loud sounds?</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

### PEACH items:

<table>
<thead>
<tr>
<th>No</th>
<th>Scale</th>
<th>Item</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Q</td>
<td>Respond to name in quiet</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Q</td>
<td>Follow verbal instructions in quiet</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>N</td>
<td>Respond to name in noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>N</td>
<td>Follow verbal instructions in noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Q</td>
<td>Follow story read aloud</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Q</td>
<td>Participate in conversation in quiet</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>N</td>
<td>Participate in conversation in noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>N</td>
<td>Participate in conversation in transport</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Q</td>
<td>Recognize voice of familiar persons</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10</td>
<td>Q</td>
<td>Converse on the phone</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>N</td>
<td>Recognize sounds in the environment</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

QUIET subscale score: \((1+2+5+6+9+10)/24*100\)

Noise subscale score: \((3+4+7+8+11)/20*100\)

Overall PEACH score: Add all scores/44*100

Comments: