Development of a Communicative Performance Scale for Pediatric Cochlear Implantation

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Objective: **Verbal communicative competence is the main objective after early cochlear implantation in deaf children. However, there are currently no validated instruments to assess a child's real-world communicative abilities. We adopted a rigorous methodological approach to systematically develop the Functioning after Pediatric Cochlear Implantation instrument (FAPCI), a family-centered communicative performance scale based on a conceptual model of functioning established by the World Health Organization.**

Design: **Qualitative instrument development was based on a systematic review of the literature, focus groups, and semistructured interviews with the parents of 2- to 5-yr-old children with cochlear implants and deafness experts. Further refinement and testing of the psychometric validity of the draft instrument was conducted using factor analysis and a cross-sectional sample of 75 parents of children with cochlear implants. Nonparametric and parametric regressions were then performed to investigate the association of FAPCI scores with duration of cochlear implant use to provide preliminary evidence for the instrument's nomological validity.**

Results: **The final 23-item, parent-proxy FAPCI instrument represents a unidimensional scale of the real-world communicative performance of 2- to 5-yr-old children with cochlear implants. The scale demonstrated excellent reliability (Cronbach's α $\geq$0.86), and there was strong evidence supporting the instrument's nomological validity. FAPCI scores were positively associated with duration of implant use ($p < .001$), and 4 yr of implant use were required before maximal FAPCI scores were achieved.**

Conclusions: **Verbal communication is a critical developmental domain that allows for optimal future emotional, cognitive, and behavioral growth. The FAPCI instrument is the first validated instrument ever designed to assess real-world communicative performance of a child with a cochlear implant. The systematic approach taken to development may enable FAPCI to be sensitive to other communication-related disorders commonly seen in childhood or to serve as a model for the development of other disorder-specific instruments.**

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For clinicians, educators, and parents of prelingually deaf children, the main objective after cochlear implantation is to ensure that the child develops the skills needed to communicate with spoken language. Verbal communicative competence has been hypothesized to serve as the foundation for a cochlear implanted child's future development of academic achievement, social versatility, and independence and quality of life in adulthood (Summerfield & Marshall, 1999). The use of valid measures of communicative competence during this period is, therefore, critical for evaluating child progress, tailoring rehabilitative therapies, and studying the role of factors that may affect the success of cochlear implantation. However, defining salient outcome measures of communicative competence during this period is not straightforward.

Currently, outcome measures used in the immediate period after cochlear implantation when most children are between 2 and 5 yr old consist of tests of speech perception/production and language (Carney & Moeller, 1998; Thoutenhoofd et al., 2005). However, empirical clinical experience and some studies (Lin et al., 2006; Vidas, Hassan, & Parnes, 1992) have demonstrated that these measures may not fully reflect a child's communicative functioning in everyday life. Namely, how a preschool child functions and performs in clinic may often differ markedly from how she behaves at home. What additional outcomes need to be assessed in these children, and how can they be measured?

Previous studies of language acquisition have demonstrated that language learning progresses in hierarchical steps from sound detection, to speech discrimination/production, and ultimately to the acquisition of verbal language (Erber, 1982). Verbal language then serves as the basis for verbal communication where language is used to convey thoughts and meaning. A conceptual framework provided by the World Health Organization's International Classification of Functioning (ICF) aids in understanding the interrelationships between speech, language, and communication and in identifying defi-

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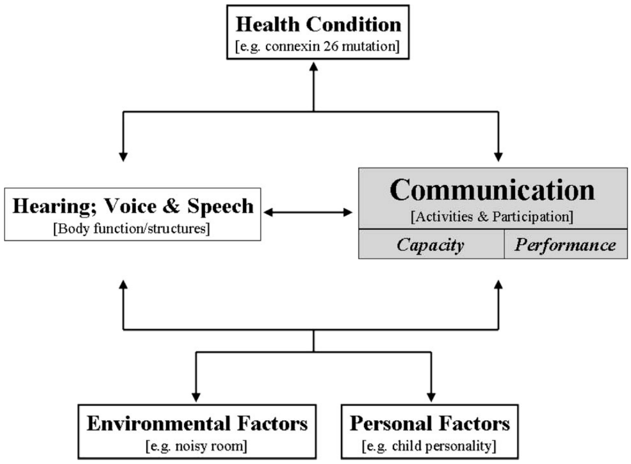

Fig. 1. Conceptual model of the International Classification of Functioning. Functioning is comprised of two components: Body functions/structures and Activities/Participation. Of relevance to deafness and cochlear implantation are body functions such as hearing, voice, and speech, which allow for communication. Communication can be further divided into communicative capacity and performance.

cits in our current approach to assessment (World Health Organization, 2001). In the ICF model, functioning is comprised of two interrelated components of body functions/structures and activities/participation (Figure 1). Domains salient to deafness would include body functions such as hearing, voice, and speech that form the basis for communication (Simeonsson, 2003). Communication can be further divided into communicative *capacity* (language ability in clinic) and *performance* (language use in a real-world environment). Environmental factors such as the situational context where communication takes place (e.g., in a noisy kitchen) or personal factors such as the child's willingness to initiate spoken conversation may minimally affect communicative capacity but would substantially affect communicative performance.

To assess a preschool child's progress after cochlear implantation, functioning must be comprehensively measured. Previous studies have demonstrated that the developmental pathway from sound detection to verbal language development is optimally active for only a finite period during early childhood as dictated by cortical plasticity (Kuhl, 2000; Locke, 1997; Sininger, Doyle, & Moore, 1999). Although the exact window for this critical period is still debated (reviewed in Davis et al., 1997), there is general consensus that periods during the first 5 yr are essential for auditory and language development. The comprehensive assessment of children with cochlear implantation during this period is, therefore, critically important. However, current approaches to assessment are limited to measures of body function (speech perception/production) and communicative capacity (language tests conducted in clinic), and few measures of communicative performance incorporating environmental and personal factors exist. Performance measures that are currently available were not specifically designed for children with cochlear implants or do not adequately define the contextual variables that are necessary to characterize the functional performance of a preschool-aged child with cochlear implants (Purdy, Farrington, Moran, Chard, & Hodgson, 2002; Sparrow, Balla, & Cicchetti, 1984; Thoutenhoofd et al., 2005). The comprehensive evaluation of communicative performance focuses on a child's behaviors at home and, therefore, incorporates the child and family's perspective (Simeonsson et al., 2003; Young, Williams, Yoshida, Bombardier, & Wright, 1996; World Health Organization, 2001). The importance of assessing this perspective is underscored by the fact that 90% of deaf children are born to hearing parents (Marschark, 1993) and the role of parent-child communicative interactions as the foundation for the child's future development of cognitive and behavioral skills (Bakeman & Adamson, 1984; Sroufe., Egeland, & Carlson, 1999).

The objectives of this study were (1) to develop the Functioning after Pediatric Cochlear Implantation (FAPCI) instrument, a communicative performance scale that was designed for 2- to 5-yr-old children with cochlear implants, using a child- and family-centered approach that combined information from parent interviews, reviews of the published literature, and the conceptual framework of the ICF; (2) to analyze the instrument's internal construct (psychometric) validity; and (3) to present preliminary evidence of nomological (external construct) validity based on our a priori hypothesis that FAPCI scores should increase with duration of implant use. Our a priori hypothesis reflects the results of previous studies that have demonstrated clear associations between duration of cochlear implant use and speech and language skills (Svirsky, Teoh, & Neuburger, 2004; Thoutenhoofd et al., 2005). Given that speech and language comprise the framework on which verbal communication is based, we hypothesized that FAPCI scores should, therefore, also increase with duration of implant use.

METHODS

This study was conducted in three phases:

(1) Qualitative instrument development consisting of domain/item identification and instrument pretesting (Table 1).
(2) Quantitative instrument validation and refinement using psychometric analysis.

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TABLE 1. Development of the FAPCI instrument

Step	Purpose	Number	Product
Phase 1: Domain and item identification			
Domain identification using the ICF*	Data generation	FAPCI investigators; 3 deafness experts	
Literature review	Data generation	31 articles; 8 instruments†	
Semistructured interviews	Data generation	12 parents of 2- to 5-yr-old children with cochlear implants	
Candidate items	Data synthesis	FAPCI investigators	Draft FAPCI instrument (56 items)
Phase 1: Qualitative pretesting			
Focus group	Refinement; face and content validity	9 parents of 2- to 5-yr-old children with cochlear implants	
Semistructured interviews	Refinement; face and content validity	5 parents of 2- to 5-yr-old children with cochlear implants	
Expert review	Refinement; face and content validity	3 deafness experts	
Instrument revision	Refinement and data synthesis	FAPCI investigators	Preliminary FAPCI instrument (60 items)
Phase 2: Quantitative testing			
Psychometric factor analysis	Item reduction; internal construct validity; reliability	75 parents of children with cochlear implants	Final FAPCI instrument (23 items)

** ICF: World Health Organization's International Classification of Functioning.*

† The eight reviewed instruments included speech, language, and generic instruments consisting of the Vineland Adaptive Behavior Scales (Sparrow et al., 1984), the Meaningful Auditory Integration Scale (Zimmerman-Phillips, Osberger, & Robbins, 1998), the Cottage Acquisition Scales for Listening, Language, and Speech (Wilkes, 1999), the Parents Views and Experiences with Pediatric CI Questionnaire (Archbold, Lutman, Gregory, O'Neill, & Nikolopoulos, 2002), the MacArthur Communicative Development Inventory (Fenson, et al., 1993), the Reynell Developmental Language Scales (Reynell & Gruber, 1990), the Auditory Behavior in Everyday Life questionnaire (Purdy et al., 2002), and the Children's Communication Checklist (Bishop, 1998).

(3) Cross-sectional analysis of the instrument's nomological validity.

All portions of this study were approved by the institutional review board at the Johns Hopkins Hospital.

Phase 1: Qualitative Development

Domain and item identification • Domain and item identification was carried out in four steps (Table 1). The framework of the ICF provided the conceptual basis for identifying aspects of communicative functioning that would need to be assessed with the FAPCI instrument. Review of the ICF framework was carried out in consultation with deafness experts who specialized in working with children with cochlear implants and consisted of otolaryngologists, speech-language pathologists, audiologists, and deaf educators. Emphasis was placed on identifying aspects of communicative performance that would be clinically-useful in tailoring individual rehabilitative treatments or in evaluating therapies/cochlear implant–related factors.

The literature review consisted of a formal systematic review of the literature as well as a review of assessment instruments currently used in early pediatric cochlear implantation. The systematic review was focused on identifying studies that have measured health-related quality of life (HRQL) in pediatric cochlear implantation (Lin & Niparko, 2006). HRQL is conceptually associated with functioning and reflects the child's perspective (Wilson & Cleary, 1995), and we used this review to identify aspects of functioning that would be of direct salience to the child and family. A defined search string and set inclusion criteria were used to review 671 citations retrieved through 5 databases (PubMed, EMBASE, CINAHL, Web of Science, and PsychInfo). Full-length manuscripts were reviewed for 31 citations of which 10 were included in the final review. An additional review of 8 currently-used instruments was also performed to identify additional themes and examples of functional performance (Table 1).

One-hour semistructured interviews were conducted with one investigator (F.L.) and parents of 2- to 5-yr-old children with cochlear implants to identify specific examples of communicative performance. Parents whose children had an upcoming audiological or rehabilitative appointment at the Johns Hopkins Listening Center were invited to participate. Parents were eligible to be interviewed if they were hearing and English- speaking and their child did not have a multisensory disorder (e.g., deaf-blind) or significant developmental delay (as judged by the child's clinician/teacher or quantitative testing with the Bayley Scales of Infant Development or Leiter International Performance Scale). The interviewer reviewed relevant ICF domains with parents, and parents were asked to provide examples of their child's behavior at home and to comment on their child's progress. Interviews were recorded, transcribed, and reviewed by inves-

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tigators, and interviews were iteratively conducted with different subjects until data saturation; that is, there was data redundancy and no new themes emerged.

The development of candidate questions was based on synthesis of the acquired data and whenever possible utilized verbatim language used by parents in interviews. This process resulted in the completion of the draft instrument which contained 56 items measuring communicative performance.

Instrument pretesting • Pretesting of the draft instrument (Table 1) was conducted with a focus group, semistructured interviews, and expert review, and this phase focused on refining the draft instrument and the assessment of face and content validity (Netemeyer, Bearden, & Sharma, 2003). All focus groups and interviews were conducted by one researcher (F.L.). A focus group of parents of 2- to 5-yr-old children with cochlear implants who were not involved in the initial development of the draft instrument was carried out at The River School, a private school partnered with Johns Hopkins that specializes in educating children with cochlear implants. Parents reviewed the instrument before the focus group, and during the meeting, they were asked to provide feedback on the content of the instrument, suitability/clarity of the items, and the response scale. The focus group session was recorded and reviewed by investigators. Semistructured interviews were carried out with parents of 2- to 5-yr-old children with cochlear implants at the Johns Hopkins Listening Center. Parents were asked to complete the draft questionnaire with the interviewer present and to express any comments or thoughts as they completed each question. The draft instrument was also reviewed by 3 deafness experts from other institutions who were not involved in the original development process. Revision of the draft instrument based on synthesis of data generated from the focus group, interviews, and expert review yielded the preliminary instrument which consisted of 60 items loosely organized into 4 subscales of adapting to the auditory environment, receptive communication, expressive communication, and socialization.

Phases 2 and 3: Quantitative Testing and Validation

Study cohort • The preliminary FAPCI instrument along with an introductory letter and a demographic intake sheet were mailed out to a sample of 2- to 5-yr-old children with cochlear implants currently seen at the Johns Hopkins Listening Center or enrolled at The River School (102 eligible families). Seventy-five families returned completed surveys yielding a response rate of 74%. Data were entered into a Microsoft Access database, and data were checked using double-data entry.

Statistical Analysis

***Psychometric analysis* •** The desired study sample size was based on obtaining good recovery of population factors in the exploratory factor analysis. Using the method of MacCallum et al., we estimated that a sample size of 60 subjects would be sufficient to achieve a κ coefficient >0.95 (good to excellent recovery) assuming wide communality between individual items and one latent factor underlying the 60 items (MacCallum, Widaman, Zhang, & Hong, 1999).

Exploratory factor analysis of FAPCI data was performed as a data reduction tool to empirically assess our assumption of unidimensionality and to optimize the scaling properties of the FAPCI instrument. Exploratory data analysis was first conducted to confirm the normality of item responses. One item was eliminated because of a high number of nonresponses (8/75). After eliminating this item, there were only a total of 6 nonresponses to individual items among the 75 completed surveys. Principal components analysis and a scree plot were first conducted to identify the number of factors to retain. Principal factor analysis using maximum likelihood estimates was then performed to develop a more parsimonious scale by eliminating items with a uniqueness >0.5. These steps were conducted iteratively until all retained items had uniqueness estimates <0.5. Rotation was unnecessary because only 1 latent factor was present.

Cronbach's α was then used to assess the internal consistency reliability of the final unidimensional set of items. Because Cronbach's α is dependent on the number of items in the scale and the variance of the latent factor in the studied group, we varied both these factors in calculating Cronbach's α to obtain a parsimonious scale that had adequate reliability in realistic groupings of subjects (Netemeyer et al., 2003). For example, in the total pool of all 2- to 5-yr-old children tested in this study, there should be a high degree of variance in communicative performance because of the different levels of cochlear implant experience and cognitive development (Thoutenhoofd et al., 2005). In contrast, there would be less variance in a subgrouping of children who were all 4 yr old, who received their implants before age 2 and who had no other associated developmental.

More items would, therefore, be needed in a scale used in the subgrouping of 4 yr-old children to achieve the same level of reliability seen in the more heterogeneous group of children. We tested

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Cronbach's α in subgroupings of children defined by age, age at cochlear implantation, and the absence of other developmental problems [2 yr old; 3 yr old/cochlear implantation before age 2; 4 yr old/cochlear implantation before age 2; 5 yr old/cochlear implantation before age 2; all subgroupings had children with no other developmental delay]. Scale length was varied until a Cronbach's α of >0.80 was consistently achieved in all groups. Determination of scale length was also influenced by the need to choose items that were representative of all 4 subscales of the instrument without redundancy.

Nomological validity • An initial test of instrument validity is to examine whether a new measure associates as expected with other measures, a type of validity known as "nomological" or external construct validity (Netemeyer et al., 2003). We tested the nomological validity of the final 23-item scale by hypothesizing that FAPCI scores should increase with increased duration of implant experience. Using the cross-sectional cohort of subjects, we explored the association between duration of implant experience and FAPCI scores using both nonparametric and parametric methods. Nonparametric regression methods (locally weighted least squares) were initially used to determine the shape of the relationship (Cleveland, 1979; Harrell, 2001). Parametric linear regression methods were then used to model the data and to test the statistical significance of the observed relationships using ordinary least squares estimates of β coefficients. Models were fitted to the observed data using cubic spline models, and differences between models were tested using a livelihood ratio test.

Linear regression model assumptions were checked. All analyses in this manuscript were carried out using Stata 8.2 software (College Station, TX). Statistical significance was set at a two-sided $\alpha < 0.05$ level.

RESULTS

Phase 1: Qualitative Instrument Development

Items were iteratively developed at meetings between three of the investigators (F.L., K.C., D.B.), using the conceptual framework of the ICF, data from interviews with parents of children with cochlear implants, and the literature review. Candidate items were developed from the hearing-world perspective and emphasized aspects of communicative functioning salient for participating in the hearing world as opposed to in Deaf culture (Ladd, 2003). A discrete, adjectival response scale was used for all items (Streiner, 1989), and there were 3 types of response formats. Frequency-based questions had response levels of "never," "rarely," "sometimes," "frequently," and "always." Quantity-based questions had response levels with either specific quantities or "almost none (0 to 4%)," "few (5 to 24%)," "some (25 to 49%)," "most (50 to 95%)," or "almost all (96 to 100%)." Example-based questions had a response format where each level contained a description or an example of a behavior, and levels corresponded to an ordinal scale of functioning adjudicated by the authors using a hearing world perspective. The draft instrument contained 56 items, and all items reflected aspects of communicative performance that are clinically-relevant (i.e., amenable to clinical intervention or useful for evaluating factors/therapies affecting cochlear implantation).

Qualitative pretesting was conducted with a focus group, semistructured interviews, and expert review to assess face and content validity and to refine the draft instrument. Face validity was assessed by having respondents comment on the clarity, response scale, and suitability of the items in measuring communicative performance. Content validity was assessed by having respondents comment on whether all aspects of communicative performance appear to have been sampled and, if not, to provide examples of missing concepts (Netemeyer et al., 2003). Extensive modifications to item wording and response scales were made based on the gathered data. One item was deleted because of ambiguity and 5 others were added based on suggestions from parents and experts. This process resulted in the development of the preliminary FACPI instrument containing 60 items loosely organized into 4 subscales.

Phase 2: Quantitative Psychometric Analysis

Characteristics of the study cohort involved in the psychometric analysis are presented in Table 2. Parent response rates to the items in the FAPCI instrument were uniformly excellent. Of 75 completed surveys, only 14 of 4500 questions (75 surveys × 60 questions/survey) were not answered, and 8 of these nonresponses were attributable to 1 item that was thought to be poorly worded. Principal components analysis of the dataset and analysis of the scree plot revealed that there was a clear 1-factor solution that was consistent with the theoretical development of the FAPCI items as a measure of communicative performance (data not shown). Subsequent iterative principal factor analysis eliminating items where <50% of the variance in the item could be explained by the latent factor of communicative performance yielded a final battery of 44 items.

The development of the final FAPCI scale was continued with this unidimensional set of items by using internal consistency reliability estimates to

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TABLE 2. Characteristics of study cohort involved in quantitative instrument refinement and testing

Characteristic	Study cohort n = 75
Age of child*	
1	1 (1.3)
2	10 (13.3)
3	14 (18.7)
4	22 (29.3)
5	20 (26.7)
6	8 (10.7)
Prelingually deaf†	75 (100)
Age at time of cochlear implantation*	
<1	9 (12.0)
1	33 (44.0)
2	20 (26.7)
3	7 (9.3)
4	6 (8.0)
Female child	41 (54.7)
Other disabling condition present‡	13 (17.3)
Survey respondent	
Mother	65 (86.7)
Father	10 (13.3)
Parent education	
High school	8 (10.7)
Some college	14 (18.7)
Completed college	25 (33.3)
Graduate school	28 (37.3)
Household income	
<$50,000	13 (17.6)
$50,000 to $100,000	29 (39.2)
>$100,000	32 (43.2)
No response	1 (1.3)

** In years.*
† Onset of severe-to-profound bilateral SNHL before 3 yr of age.
‡ As answered by parents.

determine the most parsimonious scale that would yield a Cronbach's α >0.8 in subgroupings of children homogeneous in child age, age at implantation, and the absence of other disabilities. Using the entire scale consisting of all 44 items resulted in α values consistently >0.91, suggesting that there was substantial item redundancy. A final battery of 23 items was created by choosing representative items from each of the 4 subscales and eliminating items that demonstrated overlap (e.g., parallel items in the receptive and expressive communication subscales were eliminated). This final scale of 23 items yielded acceptable Cronbach's α values with a minimum value of 0.86 seen in the most homogeneous group (3 yr old, no disability, cochlear implantation before age 2 yr). Further reductions in scale length were not performed because the 23 items were thought to be the minimum number of items needed for adequate content validity (Table 3).

Phase 3: Nomological Validity

We hypothesized that FAPCI scores would be positively associated with duration of cochlear implant use if the scale was a valid measure of communicative performance. Figure 2 depicts the relationship between FAPCI scores from the final 23-item scale and the duration of time since cochlear implantation stratified by the age at implantation (<2 or ≥2 yr old). For both groups, we observed that FAPCI scores increased with increasing duration of cochlear implant use and that, on average, maximal FAPCI scores were obtained in both groups at about 48 mo after implantation. Interestingly, children who were implanted at >2 yr old appeared to have greater FAPCI gains in the initial year after cochlear implantation but slower gains later such that both groups required approximately 4 yr of implant use before achieving maximal scores. Children who are implanted younger can, therefore, expect to achieve maximal communicative competence as measured by the FAPCI at a younger age than children implanted older because of their earlier age at implantation. We tested the statistical significance of the results observed in Figure 2 by fitting linear regression models to the data. We found strong evidence that FAPCI scores increased with increasing duration of cochlear implant use for both groups ($p < 0.001$) and that the differences in the observed trajectories in FAPCI scores for the two groups (cochlear implantation at <2 yr old versus ≥2 yr old.) were significant ($p = 0.01$).

DISCUSSION

In this study, we have developed the FAPCI instrument, a scale to measure communicative performance in 2- to 5-yr-old children utilizing an oral communication modality after cochlear implantation. This instrument was designed to complement current speech and language capacity measures and to fill a gap in our current approach to the assessment of a cochlear-implanted child's communicative competence (Figure 1). Face and content validity of the final instrument are strong because of the rigorous approach to scale development incorporating the conceptual framework of the ICF, exhaustive interviews with parents of children with cochlear implants, a systematic review, and consultation with deafness experts. Quantitative analysis also revealed strong psychometric properties. Retained items represented a unidimensional scale and were all strongly associated with the latent factor of communicative performance. Initial assessment of the nomological validity of the final FAPCI instrument using cross-sectional data also demonstrated strong evidence for our a priori hypothesis that increasing duration of implant use would be associated with increasing communicative competence.

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TABLE 3. Final 23-item FAPCI scale

Item no.	Item	Response format	Factor loading	Uniqueness
q8	How often does your child respond to phrases that s/he overhears from a nearby conversation?	F	0.72889	0.46872
q13	Given an unlimited set of possible choices, how many age-appropriate items would your child be able to point to when they are presented in spoken language without visual cues?	Q	0.90134	0.18755
q15	How many age-appropriate 2-step spoken commands presented without visual cues does your child understand?	Q	0.87199	0.23962
q17	When riding in a car, my child is able to understand . . .	E	0.88442	0.21777
q18	When listening from a different room of the house, my child is able to understand . . .	E	0.81313	0.33881
q19	When in a noisy environment, my child is able to understand . . .	E	0.85765	0.26441
q20	When using the telephone with a familiar caller, my child is able to understand . . .	E	0.83884	0.29635
q28	How often does your child appropriately answer simple questions presented in spoken language without visual cues?	F	0.83213	0.30754
q32	How many age-appropriate items would your child be able to identify with spoken language when they are pointed to?	Q	0.88632	0.21441
q34	How much of your child's speech would an adult who is not familiar with your child understand?	Q	0.86355	0.25428
q35	How does your child typically respond when greeted by a familiar person?	E	0.89705	0.19529
q36	How many people's names does your child use in spoken language?	Q	0.8766	0.23156
q37	Which statement best describes your child's singing?	E	0.85278	0.27276
q38	What is the main way that your child communicates his/her wants when not coached by an adult?	E	0.9292	0.13658
q39	How many of the following types of words/phrases does your child use in spoken language: what, where, why, inversion questions, which?	Q	0.87091	0.24151
q41	How many of the following types of words/phrases does your child use in spoken language: words to describe size or color, numbers to describe how many, words to describe quantity, plural endings, possessive ending?	Q	0.90944	0.17291
q42	How often does your child ask simple questions using spoken language?	F	0.92913	0.13676
q43	How often does your child talk about his/her experiences during the day or about a past event using simple spoken sentences?	F	0.89348	0.20173
q44	How often does your child use the past tense in spoken language?	F	0.81852	0.33004
q45	How often does your child use the negative in a 2-3 word spoken phrase?	F	0.91237	0.16762
q46	How often does your child correctly use pronouns in spoken language?	F	0.8882	0.21113
q47	How often does your child correctly use prepositions in spoken language?	F	0.90378	0.18323
q60	How often does your child initiate a spoken conversation with another child?	F	0.74636	0.44294

Detailed instructions, specific examples, and tips for responding to all items are provided with questions in the actual FAPCI instrument. Response format: F = frequency-based questions (response levels of "never," "rarely," "sometimes," "frequently," and "always"); Q = quantity-based questions [response levels with either specific quantities or "almost none (0 to 4%)," "few (5 to 24%)," "some (25 to 49%)," "most (50 to 95%)," or "almost all (96 to 100%)"]; E = example-based questions (response levels contain a description or an example of a behavior, and levels correspond to an ordinal scale of functioning adjudicated by the authors). Factor loadings represent the correlation between the item and the latent factor of communicative performance. Alternatively, squared values of the factor loading are the percent of variance in the item explained by the latent factor. Uniqueness values indicate the percent of variance in the item that cannot be explained by the latent factor. A copy of the final instrument is available from the authors. The maximum possible score on the FAPCI is 115.

The application of the FAPCI instrument to the assessment of a cochlear-implanted child's communicative competence is important for two reasons. First, effective bidirectional communication in early parent-child interactions irrespective of language modality has been shown to be critical for optimal childhood development (Marschark, 1993; Vaccari & Marschark, 1997). Given that 90% of deaf children are born to hearing parents, there is a need to assess how well young children with cochlear implants are able to verbally communicate with their parents (Marschark, 1993). General clinical observations as well as our previous research (Lin et al., 2006) have demonstrated that current verbal language measures may not capture a child's communicative performance. Although verbal language remains the cornerstone on which verbal communication is based, there are numerous other environmental and personal factors which can affect a child's communicative competence that are not reflected in current language instruments. The FAPCI instrument was designed to address this deficiency by including

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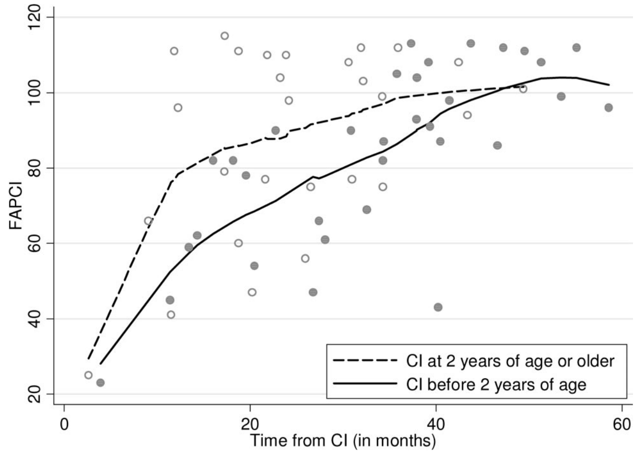

Fig. 2. Nonparametric mean trajectory of FAPCI scores over duration of time from cochlear implantation. Open circles = Cochlear implantation at 2 yr of age or older; closed circles = cochlear implantation before 2 yr of age. The maximal possible score on the FAPCI is 115.

situational and behavioral contexts to directly assess a child's verbal communicative competence rather than just language ability. Second, the current emphasis in pediatrics on patient- centered assessments emphasizes the use of outcome measures based on effectiveness rather than efficacy (Freed & Uren, 2006). In particular, with respect to pediatric cochlear implantation, there is a need to use outcome measures that capture a child's real-world communicative performance rather than just a child's language abilities in a clinic room.

The FAPCI instrument was designed to have sufficient breadth to be used as either a discriminative or evaluative instrument. A discriminative instrument allows for observing differences *between* patients at a given point in time. For example, the FAPCI instrument could be used to distinguish between groups of similar children who have used different speech processing algorithms or who have received unilateral versus bilateral implants. The principal measure of the discriminative power of an instrument is the instrument's reliability which reflects the ratio of the signal (differences between subjects) to noise (differences within subjects) (Juniper, Guyatt, & Jaeschke, 1996). The FAPCI instrument demonstrated excellent reliability with Cronbach α scores of >0.86 even in homogeneous subgroups of subjects. In contrast to discriminative instruments, an evaluative instrument measures change *within* an individual over time. For example, a child's progress in communicative competence could be annually quantified using the FAPCI instrument from the time that a child receives an implant at 18 mo to when the child begins kindergarten. The FAPCI instrument with item response scales that reflect different levels of communicative functioning was explicitly designed to objectively evaluate an individual child's development over time.

Our experience with administering the FAPCI instrument to parents of children with cochlear implants in pilot studies has also been highly successful. Parents overwhelmingly reported that they enjoyed completing the instrument since the questions and response items allowed them to better understand the course of their child's developmental progress after implantation. Parents also reported that completing the instrument alerted them to different facets of daily communication (e.g., communicating face-to-face in a noisy setting) that they needed to work on with their children and address with the child's audiologist or rehabilitation therapist. Parents generally took 5 minutes to complete the instrument, and instrument scoring by the examiner took <2 minutes.

Limitations

As with other proxy instruments, the primary limitation of the FAPCI instrument is that it is an indirect measure of the target construct (the child's communicative performance) that relies on parent-proxy responses. Previous studies of parent-proxy measures have suggested that proxy responses for children could potentially be biased (De Civita et al., 2005; Eiser & Morse, 2001a; Eiser & Morse, 2001b). We believe that the current design and scope of the FAPCI instrument effectively overcomes these limitations. First, although parent-proxy measures of child health-related quality of life have demonstrated poor correlation between parent and child scores for emotional or subjective HRQL domains, there has been much better agreement between parent and child scores for measures of objective functioning (Eiser et al., 2001b). Second, one of the main purposes of early communicative functioning in deaf children with cochlear implants to allow for effective parent-child interactions that serve as the basis for future child development. Parental assessments of childhood communicative functioning then should be a valid approach to assessing child communicative performance since communication is dependent on bidirectional interactions between parent and child where either party's assessment of communication should be equally valid. Previous work has clearly established the importance of the parent-child communicative dyad for future language growth and optimal childhood development (Hart & Risley, 1995; Marschark, 1993; Vaccari et al., 1997). Third, item response scales for all FAPCI items consist of objective response levels that should minimize the subjectivity associated with tradi-

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tional Likert scales that ask for the subject's level of agreement with a given statement. Finally, although direct measures of communicative performance that rely on video recordings of parent-child interactions (Knutson, Boyd, Reid, Mayne, & Fetrow, 1997; Quittner, Leibach, & Marciel, 2004) are possible, they are often not practically feasible given the expense and time required to obtain recordings and objectively code the observed patterns of behavior. Furthermore, these recordings when conducted in a clinic setting are also subject to potential bias since they may not be representative of real world communicative performance where environmental factors (e.g., background noise at home from the television or other siblings) are present.

Our use of cross-sectional rather than longitudinal data limits the conclusions that can be drawn about the expected trajectories of FAPCI scores over time shown in Figure 3. Although our results demonstrate a positive association between FAPCI scores and duration of implantation ($p < 0.001$) and support the nomological validity of the instrument, the shape of the observed trajectories are most likely only approximate. In charting the mean trajectory of FAPCI scores with cross-sectional data, the assumption is made that subjects would generally have similar communicative levels based on duration of cochlear implant use. Although the testing of the significance of a positive association between FAPCI scores and duration of cochlear implant would generally be robust to this assumption, the shape of the trajectory in Figure 2 may not be. Therefore, we can not definitively conclude how the trajectory of communicative performance may differ between children implanted before or after age 2 yr.

As such, our current results without the addition of other speech and language data provide preliminary evidence for the nomological validity of FAPCI. Currently, we are following our present study cohort longitudinally in addition to using FAPCI alongside other speech and language measures to allow us to better estimate the expected trajectory of FAPCI with other speech and language measures over time. Given the conceptual framework describing the interaction between speech, language, and communication (Figure 1), we would hypothesize that FAPCI scores should be closely associated with other speech and language measures but may be affected by environmental factors such as the child's home situation. Similarly, personal factors such as increasing cognitive maturity seen as children grow older would also be expected to be positively related to FAPCI scores regardless of language ability. Indeed, with the current cohort, we did find that FAPCI scores were positively associated with age even when controlling for duration of cochlear implant use (data not shown).

CONCLUSIONS

During the toddler years, verbal communication is a critical developmental domain that allows for optimal future emotional, cognitive, and behavioral growth. Currently, however, no validated measures exist to assess a young child's real-world communicative abilities. The FAPCI instrument was specifically designed to fill a gap in our current approach to the assessment of deaf children receiving cochlear implants. Preliminary evidence for instrument validity is strong, and the rigorous methodological approach taken to instrument development may enable FAPCI to be sensitive to other communication-related disorders commonly seen in childhood or to serve as a model for the development of other disorder-specific instruments.

The final version of the FAPCI instrument is available for use by contacting the architects of the instrument at fapci@jhmi.edu.

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REFERENCES

Archbold, S. M., Lutman, M. E., Gregory, S., O'Neill, C., Nikolopoulos, T. P. (2002). Parents and their deaf child: their perceptions three years after cochlear implantation. *Deafness and Education International*, *4*, 12–40.

Bakeman, R., Adamson, L. B. (1984). Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Development*, *55*, 1278–1289.

Bishop, D. V. (1998). Development of the Children's Communication Checklist (CCC): A method for assessing qualitative aspects of communicative impairment in children. *Journal of Child Psychology and Psychiatry*, *39*, 879–891.

Carney, A. E., Moeller, M. P. (1998). Treatment efficacy: Hearing loss in children. *Journal of Speech, Language, and Hearing Research*, *41*, S61–S84.

Cleveland, W. S. (1979). Robust locally weighted regression and smoothing scatterplots. *Journal of the American Statistical Association*, *74*, 829–836.

Davis, A., Bamford, J., Wilson, I., Ramkalawan, T., Forshaw, M., Wright, S. (1997). A critical review of the role of neonatal hearing screening in the detection of congenital hearing impairment. *Health Technology Assessment*, *1*, i–176.

De Civita, M., Regier, D., Alamgir, A. H., Anis, A. H., Fitzgerald, M. J., Marra, C. A. (2005). Evaluating health-related quality-of-life studies in paediatric populations: Some conceptual,

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methodological and developmental considerations and recent applications. *Pharmacoeconomics*, *23*, 659–685.

Eiser, C., Morse, R. (2001a). Can parents rate their child's health-related quality of life? Results of a systematic review. *Quality. Life Research*, *10*, 347–357.

Eiser, C., Morse, R. (2001b). The measurement of quality of life in children: Past and future perspectives. *Journal of Developmental and Behavioral Pediatrics, 22*, 248–256.

Erber, N. (1982). *Auditory Training*. Washington, D.C.: AG Bell Association for the Deaf.

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P.,. (1993). *The MacArthur Communicative Development Inventories: User's Guide and Technical Manual.* Baltimore: Paul H. Brokes Publishing Co.

Freed, G. L., Uren, R. L. (2006). Pay-for-performance: An overview for pediatrics. *Journal of Pediatrics, 149*, 120–124.

Harrell, F. E. (2001). *Regression Modeling Strategies*. New York: Springer-Verlag.

Hart, B., Risley, T. (1995). Meaningful differences in the everyday experience of young American children. Baltimore: Paul H. Brookes Publishing Co.

Juniper, E., Guyatt, G., Jaeschke, R. (1996). How to develop and validate a new health-related quality of life instrument. In B. Spilker (Ed.). *Quality of Life and Pharmacoeconomics in Clinical Trials*, 2nd ed. (pp. 49–56). Baltimore: Lippincott Williams & Wilkins.

Knutson, J. F., Boyd, R. C., Reid, J. B., Mayne, T., Fetrow, R. (1997). Observational assessments of the interaction of implant recipients with family and peers: Preliminary findings. *Otolaryngology–Head and Neck Surgery*, *117*, 196–207.

Kuhl, P. K. (2000). A new view of language acquisition. *Proceedings of the National Academy of Sciences of the United States of America*, *97*, 11850–11857.

Ladd, P. (2003). Understanding Deaf Culture: In Search of Deafhood. North Somerset, UK: Multilingual Matters Limited.

Lin, F. R., Niparko, J. K. (2006). Measuring health-related quality of life after pediatric cochlear implantation: a systematic review. *International Journal of Pediatric Otorhinolaryngology*, *70*, 1695–1706.

Lin, F. R., Wang, N., Fink, N., Quittner, A., Eisenberg, L., Tobey, E, et al. (2006). Association of speech and language measures with parental perceptions of development after early cochlear implantation (submitted for publication). *Otology and Neurotology*.

Locke, J. L. (1997). A theory of neurolinguistic development. *Brain and Language*, *58*, 265–326.

MacCallum, R., Widaman, K., Zhang, S., Hong, S. (1999). Sample size in factor analysis. *Psychological Methods*, *4*, 84–99.

Marschark, M. (1993). Origins and interactions in the social, cognitive, and language development of deaf children. In Marschark M., Clark M. D. (Eds.). *Psychological perspectives on deafness* (pp. 7–26). Hillsdale, NJ: Lawrence Erlbaum Associates.

Marschark, M. (1993). Psychological development of deaf children. New York: Oxford University Press.

Netemeyer, R., Bearden, W., Sharma, S. (2003). *Scaling Procedures.* Thousand Oaks, CA: Sage Publications, Inc.

Purdy, S. C., Farrington, D. R., Moran, C. A., Chard, L. L., Hodgson, S. A. (2002). A parental questionnaire to evaluate children's Auditory Behavior in Everyday Life (ABEL). *American Journal of Audiology*, *11*, 72–82.

Quittner, A. L., Leibach, P., Marciel, K. (2004). The impact of cochlear implants on young deaf children: New methods to assess cognitive and behavioral development. *Archives of Otolaryngology–Head and Neck Surgery*, *130*, 547–554.

Reynell, J., Gruber, C. (1990). *Reynell Developmental Language Scales.* Los Angeles: Western Psychological Services.

Simeonsson, R. J. (2003). Classification of communication disabilities in children: Contribution of the International Classification on Functioning, Disability and Health. *International Journal of Audiology, 142(Suppl)*, S2–S8.

Simeonsson, R. J., Leonardi, M., Lollar, D., Bjorck-Akesson, E., Hollenweger, J., Martinuzzi, A. (2003). Applying the International Classification of Functioning, Disability and Health (ICF) to measure childhood disability. *Disability and Rehabilitation*, *25*, 602–610.

Sininger, Y. S., Doyle, K. J., Moore, J. K. (1999). The case for early identification of hearing loss in children: Auditory system development, experimental auditory deprivation, and development of speech perception and hearing. *Pediatric Clinics of North America*, *46*, 1–14.

Sparrow, S., Balla, D., Cicchetti, D. (1984). *Vineland Adaptive Behavior Scales*. Circle Pines, MN: AGS Publishing.

Sroufe, L., Egeland, B., Carlson, E. (1999). One social world: The integrated development of parent-child and peer relationships. In Collins W. A., Laursen B. (Eds.). *Relationships as Developmental Contexts (Minnesota Symposia on Child Psychology)* (pp. 241–261). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Streiner, D. L. (1989). *Health Measurement Scales*. New York: Oxford University Press, Inc.

Summerfield, A. Q., Marshall, D. H. (1999). Paediatric cochlear implantation and health-technology assessment. *International Journal of Pediatric Otorhinolaryngology*, *47*, 141–151.

Svirsky, M. A., Teoh, S. W., Neuburger, H. (2004). Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation. *Audiology and Neurootology*, *9*, 224–233.

Thoutenhoofd, E., Archbold, S., Gregory, S., Lutman, M. E., Nikolopoulos, T. P., Sach, T. (2005). *Paediatric Cochlear Implantation: Evaluating Outcomes*. West Sussex: Wiley.

Vaccari, C., Marschark, M. (1997). Communication between parents and deaf children: implications for social-emotional development. *Journal of Child Psychology and Psychiatry*, *38*, 793–801.

Vidas, S., Hassan, R., Parnes, L. S. (1992). Real-life performance considerations of four pediatric multi-channel cochlear implant recipients. *Journal of Otolaryngology*, *21*, 387–393.

Wilkes, E. (1999). Cottage Acquisition Scales for Listening, Language and Speech. San Antonio: Sunshine Cottage School for Deaf Children.

Wilson, I. B., Cleary, P. D. (1995). Linking clinical variables with health-related quality of life: A conceptual model of patient outcomes. *Journal of the American Medical Association*, *273*, 59–65.

World Health Organization. (2001). International classification of functioning, disability, and health. ICF. Geneva: WHO.

Young, N. L., Williams, J. I., Yoshida, K. K., Bombardier, C., Wright, J. G. (1996). The context of measuring disability: does it matter whether capability or performance is measured? *Journal of Clinical Epidemiology*, *49*, 1097–1101.

Zimmerman-Phillips, S., Osberger, M. J., Robbins, A. M. (1998). *Infant-Toddler Meaningful Auditory Integration Scale*. Sylmar, CA: Advanced Bionics Corporation.

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