

Ears[®]

Evaluation of Auditory Responses to Speech

Normative Data





Introduction

After learning about their child's hearing problems and choosing the treatment option of a cochlear implant (CI), parents often ask professionals about the auditory and language development, as well as the level of language proficiency that may be expected of their child following implantation. Reliable answers are crucial for setting appropriate parental expectations and for setting up a suitable therapeutic programme. A child's level of progress determines whether he may be integrated into the mainstream educational system.

When attempting to answer the parents' question about their child's potential performance, clinicians have to take influencing factors such as age at implantation, aetiology, age at onset of deafness and the degree of hearing loss into account. The impact of these factors is further complicated by the child's overall development, motor skills, memory and social factors such as gender, family size and parents' background.

In 1995, Dianne J. Allum-Mecklenburg initiated the development of a comprehensive assessment tool in cooperation with audiologists, otolaryngologists, psycholinguists, psychologists and speech therapists, supported by MED-EL. The group collected and combined different tests, developed and adapted the tests in order to systematise these tests into a common standard, and facilitated its adaptation into different languages and cultures. The assessment tool was named EARS (Evaluation of Auditory Responses to Speech) and has been adapted to more than 20 languages since its first presentation in 1996. This tool is suitable for children aged 3 to 18 years. Its main goals are:

- 1) to evaluate auditory perception development in severely and profoundly hearing-impaired children who have received a CI,
- 2) to provide support for device fitting and the rehabilitation of these children, and

- 3) to provide an instrument for the long-term assessment of children with CIs. Furthermore, EARS with its multilanguage international perceptual tests, has been compiled to evaluate and compare perceptual skills and performances of children with CIs within and across languages.

The EARS tests do not establish the hearing ability of the child but rather assess the ability to comprehend the meaning of sounds, words and sentences. The approach is holistic because it involves not only the objective measurement of the child's ability in detection, discrimination, identification, recognition, and comprehension but also the subjective measurement of parents' and teachers' judgments of a child's achievements using a set of questionnaires.

Results from individual clinics using the EARS assessment tool have already been published and show improved auditory perception over time in both homogenous and heterogeneous groups of cochlear implant users. To overcome the problem of small sample sizes and to obtain a more universal statement of outcomes, MED-EL initiated a multi-centre, multi-country study.

The MED-EL study included children who became deaf both pre- and post-lingually, and received their implants at different ages. The sample, by nature of its size, also included children with multiple-handicaps and/or additional difficulties. Having such a large pool of data (n=765) allows for greater generalisation of what is in essence a heterogeneous group, probably representing the general sample of children with cochlear implants. In-depth analyses of this data pool assist us in discussing general improvement over time on speech perception scores. The data gathered over the past 13 years from 35 clinics in 15 countries have been thoroughly analyzed and a normative baseline established. These normative values are presented in this manual.

Explaining the Normative Data

Using the normative tables, you can look at the expected age at implantation and then project the anticipated outcome for a certain test result at a certain time after receiving a CI.

Using the LiP test as an example, we can see the median percentage achieved by the single age groups at different testing times after implantation. Children older than 5 years at the time of their implantation reached the maximum score on the LiP 1 year after implantation. Children between 3 and 5 years at the time of their implantation scored highest 1.5 years after implantation. The children implanted youngest (<3 years) reached their highest possible value approximately 2 years after implantation.

Another way of looking at the data would be to ask: what score would a child achieve if he received a CI between 1 to 2 years of age and had 6 months of device experience? If we refer to Table 1, we see that the expected score would be 59.5%.

Table 1: Median LiP score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	LiP pre (%)	LiP ff* (%)	LiP 1 month (%)	LiP 3 months (%)	LiP 6 months (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	1.2	6.0	8.3	21.4	40.5
1 – 2	2.4	7.1	23.8	42.9	59.5
2 – 3	4.8	11.9	35.7	50.0	66.7
3 – 4	9.5	38.1	47.6	64.3	82.1
4 – 5	14.3	38.1	61.9	83.3	90.5
5 – 6	29.8	45.2	70.2	85.7	92.9
6 – 7	31.0	71.4	86.9	88.1	96.4
>7	51.2	69.0	85.7	95.2	97.6

* ff = first fitting

Table 2: Median LiP score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	LiP 1 year (%)	LiP 1.5 years (%)	LiP 2 years (%)	LiP 3 years (%)	LiP 4 years (%)	LiP 5 years (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	57.14	65.5	100	-	-	-
1 – 2	69.05	94.0	97.6	100	100	100
2 – 3	88.10	97.6	100	100	100	100
3 – 4	95.24	100	100	100	100	100
4 – 5	97.62	100	100	100	100	100
5 – 6	100	100	100	100	100	100
6 – 7	100	100	100	100	100	100
>7	100	100	100	100	100	100

Normative Data

Listening Progress Profile (LiP)

The LiP was adapted from a test developed by Archbold [1]. The LiP is a profile of the development of early listening skills, including environmental as well as speech sounds. Responses are recorded based on the frequency the response is demonstrated: "always," "sometimes" or "never." These responses may be elicited or observed.

Table 3: Median LiP score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	LiP pre (%)	LiP ff* (%)	LiP 1 month (%)	LiP 3 months (%)	LiP 6 months (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	1.2	6.0	8.3	21.4	40.5
1 – 2	2.4	7.1	23.8	42.9	59.5
2 – 3	4.8	11.9	35.7	50.0	66.7
3 – 4	9.5	38.1	47.6	64.3	82.1
4 – 5	14.3	38.1	61.9	83.3	90.5
5 – 6	29.8	45.2	70.2	85.7	92.9
6 – 7	31.0	71.4	86.9	88.1	96.4
> 7	51.2	69.0	85.7	95.2	97.6

* ff = first fitting

Table 4: Median LiP score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	LiP 1 year (%)	LiP 1.5 years (%)	LiP 2 years (%)	LiP 3 years (%)	LiP 4 years (%)	LiP 5 years (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	57.14	65.5	100	-	-	-
1 – 2	69.05	94.0	97.6	100	100	100
2 – 3	88.10	97.6	100	100	100	100
3 – 4	95.24	100	100	100	100	100
4 – 5	97.62	100	100	100	100	100
5 – 6	100	100	100	100	100	100
6 – 7	100	100	100	100	100	100
> 7	100	100	100	100	100	100

Monosyllabic Trochee Polysyllabic Word Test (MTP)

The MTP is based on the MTS devised by Erber and Alencewicz [2]. This test is made up of monosyllabic, trochee, spondaic and polysyllabic words. During testing the child is asked to point to/repeat the word. Results are scored on a confusion matrix, which displays both correct identifications and errors. Responses may be scored in two ways: percent words recognised correctly and percent words categorised correctly by stress pattern. Thus, even if the child cannot understand these words, his ability to perceive word patterns can be evaluated. Answers were grouped and analysed in the following way: 3, 6 and 12 words and 3, 6 and 12 word patterns.

Table 5: Median MTP 3 Pattern score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MTP 3 Patterns pre (%)	MTP 3 Patterns ff* (%)	MTP 3 Patterns 1m (%)	MTP 3 Patterns 3m (%)	MTP 3 Patterns 6m (%)
Chance score	33	33	33	33	33
0 - 1	-	-	-	-	-
1 - 2	0	0	8,3	8,3	66,6
2 - 3	0	0	4,1	25,0	79,1
3 - 4	0	25,0	33,3	66,6	91,6
4 - 5	33,3	16,6	33,3	58,3	79,1
5 - 6	37,5	50,0	70,8	75,0	87,5
6 - 7	54,1	62,5	83,3	100	95,8
> 7	66,6	83,3	91,6	100	100

* ff = first fitting

Table 6: Median MTP 3 Pattern score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MTP 3 Patterns 1 year (%)	MTP 3 Patterns 1,5 years (%)	MTP 3 Patterns 2 years (%)	MTP 3 Patterns 3 years (%)	MTP 3 Patterns 4 years (%)	MTP 3 Patterns 5 years (%)
Chance score	33	33	33	33	33	33
0 - 1	50	100	-	-	-	-
1 - 2	83,3	100	95,8	100	100	-
2 - 3	100	100	100	100	100	-
3 - 4	100	100	100	100	91,7	100
4 - 5	100	100	100	100	100	100
5 - 6	100	100	100	100	100	-
6 - 7	100	100	100	100	100	100
> 7	100	100	100	100	95,8	100

Table 7: Median MTP 3 Word score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MTP 3 Words pre (%)	MTP 3 Words ff* (%)	MTP 3 Words 1m (%)	MTP 3 Words 3m (%)	MTP 3 Words 6m (%)
Chance score	33	33	33	33	33
0 – 1	-	-	-	-	-
1 – 2	0	0	8,3	8,3	66,6
2 – 3	0	0	4,1	25,0	75,0
3 – 4	0	25,0	33,3	66,6	91,6
4 – 5	33,3	16,6	33,3	58,3	66,6
5 – 6	37,5	50,0	70,8	75,0	87,5
6 – 7	54,1	62,5	83,3	100	87,5
> 7	58,3	75,0	83,3	91,6	100

* ff = first fitting

Table 8: Median MTP 3 Word score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MTP 3 Words 1 year (%)	MTP 3 Words 1,5 years (%)	MTP 3 Words 2 years (%)	MTP 3 Words 3 years (%)	MTP 3 Words 4 years (%)	MTP 3 Words 5 years (%)
Chance score	33	33	33	33	33	33
0 – 1	50	100	-	-	-	-
1 – 2	83,3	100	95,8	100	100	-
2 – 3	100	100	100	100	100	-
3 – 4	100	100	100	100	91,7	100
4 – 5	100	100	100	100	100	100
5 – 6	100	100	100	100	100	-
6 – 7	100	100	100	100	100	100
> 7	100	100	100	100	95,8	100

Table 9: Median MTP 6 Pattern score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MTP 6 Patterns pre (%)	MTP 6 Patterns ff* (%)	MTP 6 Patterns 1m (%)	MTP 6 Patterns 3m (%)	MTP 6 Patterns 6m (%)
Chance score	33	33	33	33	33
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	91,6
2 - 3	0	50,0	61,1	77,7	88,8
3 - 4	22,2	52,7	88,8	94,4	88,8
4 - 5	77,7	83,3	63,8	94,4	88,8
5 - 6	86,1	83,3	83,3	94,4	94,4
6 - 7	83,3	72,2	88,8	94,4	94,4
> 7	77,7	83,3	83,3	94,4	94,4

* ff = first fitting

Table 10: Median MTP 6 Pattern score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MTP 6 Patterns 1 year (%)	MTP 6 Patterns 1,5 years (%)	MTP 6 Patterns 2 years (%)	MTP 6 Patterns 3 years (%)	MTP 6 Patterns 4 years (%)	MTP 6 Patterns 5 years (%)
Chance score	33	33	33	33	33	33
0 - 1	-	-	-	-	-	-
1 - 2	100	100	100	100	100	-
2 - 3	100	100	100	100	100	-
3 - 4	94,4	100	94,4	100	94,4	100
4 - 5	100	91,7	100	100	100	100
5 - 6	100	88,9	100	100	100	-
6 - 7	100	100	100	100	100	83,3
> 7	100	100	94,4	100	77,8	100

Table 11: Median MTP 6 Word score of the single age groups 1 year to 5 years after implantation
(from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MTP 6 Words pre (%)	MTP 6 Words ff* (%)	MTP 6 Words 1m (%)	MTP 6 Words 3m (%)	MTP 6 Words 6m (%)
Chance score	16	16	16	16	16
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	66,6
2 - 3	0	38,8	27,7	66,6	91,6
3 - 4	38,8	47,2	83,3	77,7	72,2
4 - 5	77,7	75,0	61,1	88,8	80,5
5 - 6	75,0	77,7	63,8	80,5	88,8
6 - 7	55,5	61,1	83,3	77,7	83,3
> 7	61,1	61,1	61,1	83,3	88,8

* ff = first fitting

Table 12: Median MTP 6 Word score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	MTP 6 Words 1 year (%)	MTP 6 Words 1,5 years (%)	MTP 6 Words 2 years (%)	MTP 6 Words 3 years (%)	MTP 6 Words 4 years (%)	MTP 6 Words 5 years (%)
Chance score	16	16	16	16	16	16
0 - 1	-	-	-	-	-	-
1 - 2	100	100	100	100	100	-
2 - 3	100	100	100	100	100	-
3 - 4	91,7	83,3	94,4	100	72,2	100
4 - 5	100	88,9	100	100	100	100
5 - 6	97,2	88,9	100	94,4	100	-
6 - 7	88,9	91,7	94,4	100	100	83,3
> 7	94,4	100	88,9	100	77,8	100

Table 13: Median MTP 12 Pattern score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MTP 12 Patterns pre (%)	MTP 12 Patterns ff* (%)	MTP 12 Patterns 1m (%)	MTP 12 Patterns 3m (%)	MTP 12 Patterns 6m (%)
Chance score	33	33	33	33	33
0 - 1	-	-	-	-	-
1 - 2	-	-	-	87,5	100
2 - 3	0	66,6	62,5	100	100
3 - 4	20,8	37,5	81,2	91,6	91,6
4 - 5	85,4	84,3	83,3	95,8	95,8
5 - 6	41,6	70,8	91,6	100	93,7
6 - 7	75	70,8	91,6	95,8	100
> 7	75	83,3	91,6	95,8	95,8

* ff = first fitting

Table 14: Median MTP 12 Pattern score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MTP 12 Patterns 1 year (%)	MTP 12 Patterns 1,5 years (%)	MTP 12 Patterns 2 years (%)	MTP 12 Patterns 3 years (%)	MTP 12 Patterns 4 years (%)	MTP 12 Patterns 5 years (%)
Chance score	33	33	33	33	33	33
0 - 1	-	-	-	-	-	-
1 - 2	100	100	100	100	100	-
2 - 3	100	100	100	100	97,9	-
3 - 4	91,7	100	100	100	97,9	100
4 - 5	95,8	100	100	100	100	100
5 - 6	95,8	93,8	100	100	100	100
6 - 7	100	100	100	97,9	89,6	54,2
> 7	95,8	95,8	95,8	95,8	100	100

Table 15: Median MTP 12 Word score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MTP 12 Words pre (%)	MTP 12 Words ff* (%)	MTP 12 Words 1m (%)	MTP 12 Words 3m (%)	MTP 12 Words 6m (%)
Chance score	8	8	8	8	8
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	87,5
2 - 3	0	-	27,0	45,8	100
3 - 4	6,2	33,3	70,8	41,6	83,3
4 - 5	85,4	-	75,0	95,8	91,6
5 - 6	29,1	45,8	70,8	83,3	85,4
6 - 7	45,8	50,0	83,3	91,6	91,6
> 7	50,0	54,1	75,0	85,4	91,6

* ff = first fitting

Table 16: Median MTP 12 Word score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MTP 12 Words 1 year (%)	MTP 12 Words 1,5 years (%)	MTP 12 Words 2 years (%)	MTP 12 Words 3 years (%)	MTP 12 Words 4 years (%)	MTP 12 Words 5 years (%)
Chance score	8	8	8	8	8	8
0 - 1	-	-	-	-	-	-
1 - 2	100	91,7	100	100	97,9	100
2 - 3	100	100	100	100	100	95,8
3 - 4	91,7	100	100	100	93,8	100
4 - 5	91,7	100	100	100	100	100
5 - 6	87,5	91,7	100	100	100	100
6 - 7	95,8	95,8	97,9	95,8	83,3	54,2
> 7	87,5	91,7	95,8	91,7	100	100

Monosyllable Closed-Set Test

This monosyllable test was devised by Schneider et al [3]. Two word lists choices are available (one with four and one with twelve words) according to the child's abilities and familiarity with vocabulary. The test may be monosyllabic or bisyllabic according to the language, as certain languages, e.g. Italian, do not have many meaningful monosyllabic words.

Table 17: Median Closed-set Words 4 score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Closed Set Words 4 pre (%)	Closed Set Words 4 ff* (%)	Closed Set Words 4 1m (%)	Closed Set Words 4 3m (%)	Closed Set Words 4 6m (%)
Chance score	25	25	25	25	25
0 - 1	-	-	-	-	-
1 - 2	0	0	8,3	8,3	66,6
2 - 3	0	0	4,1	25	75
3 - 4	0	25	33,3	66,6	91,6
4 - 5	33,3	16,6	33,3	58,3	66,6
5 - 6	37,5	50	70,8	75	87,5
6 - 7	54,1	62,5	83,3	100	87,5
> 7	58,3	75	83,3	91,6	100

* ff = first fitting

Table 18: Median Closed-set Words 4 score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	Closed Set Words 4 1 year (%)	Closed Set Words 4 1,5 years (%)	Closed Set Words 4 2 years (%)	Closed Set Words 4 3 years (%)	Closed Set Words 4 4 years (%)	Closed Set Words 4 5 years (%)
Chance score	25	25	25	25	25	25
0 - 1	50	100	-	-	-	-
1 - 2	83,3	100	95,8	100	100	-
2 - 3	100	100	100	100	100	-
3 - 4	100	100	100	100	91,6	100
4 - 5	100	100	100	100	100	100
5 - 6	100	100	100	100	100	-
6 - 7	100	100	100	100	100	100
> 7	100	100	100	100	95,8	100

Table 19: Closed-set Words 12 score of the single age groups 1 year to 5 years after implantation
(from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Closed Set Words 12 pre (%)	Closed Set Words 12 ff* (%)	Closed Set Words 12 1m (%)	Closed Set Words 12 3m (%)	Closed Set Words 12 6m (%)
Chance score	8	8	8	8	8
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	-
2 - 3	-	-	-	79,1	95,8
3 - 4	45,8	-	79,1	91,6	75
4 - 5	70,8	-	66,6	81,2	85,4
5 - 6	-	20,8	-	66,6	93,7
6 - 7	54,1	64,5	97,9	91,6	83,3
> 7	58,3	37,5	58,3	66,6	85,4

* ff = first fitting

Table 20: Median Closed-set Words 12 score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	Closed Set Words 12 1 year (%)	Closed Set Words 12 1,5 year (%)	Closed Set Words 12 2 year (%)	Closed Set Words 12 3 year (%)	Closed Set Words 12 4 year (%)	Closed Set Words 12 5 year (%)
Chance score	8	8	8	8	8	8
0 - 1	-	-	-	-	-	-
1 - 2	100	93,7	100	100	95,8	100
2 - 3	95,8	95,8	100	95,8	100	-
3 - 4	87,5	100	97,9	95,8	91,6	100
4 - 5	93,7	100	95,8	100	100	100
5 - 6	75	87,5	95,8	83,3	87,5	97,9
6 - 7	91,6	100	91,6	87,5	93,75	62,5
> 7	83,3	85,4	87,5	87,5	79,1	79,1

Tyler Holstad Closed-Set Sentence Test

This test was adapted from Tyler and Holstad [4]. The test was included because it has three main advantages:

- 1) It is a sentence level test, which is more realistic as natural speech occurs at a rapid rate. Co-articulation makes word boundaries less precise and this requires the listener to make decisions about speech in an ongoing, continuous manner.
- 2) Learning effects associated with repeated presentations are minimised since the children know all the alternatives for each item.
- 3) The test is independent of vocabulary, language and cognitive maturation. However, the test was extended from the original two levels to four levels, as preliminary findings suggested that the differences in memory and linguistic skill were too large between the two levels.

Table 21: Median Matrix A score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Closed Set Sent. A pre (%)	Closed Set Sent. A ff* (%)	Closed Set Sent. A 1m (%)	Closed Set Sent. A 3m (%)	Closed Set Sent. A 6m (%)
Chance score	50	50	50	50	50
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	-
2 - 3	-	-	-	-	10,8
3 - 4	-	83,3	-	70	71,6
4 - 5	30	-	-	65	69,1
5 - 6	21,6	36,6	-	61,6	71,6
6 - 7	40	-	100	88,3	76,6
> 7	81,6	85	73,3	75	76,6

* ff = first fitting

Table 22: Median Matrix A score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	Closed Set Sent. A 1 year (%)	Closed Set Sent. A 1,5 year (%)	Closed Set Sent. A 2 year (%)	Closed Set Sent. A 3 year (%)	Closed Set Sent. A 4 year (%)	Closed Set Sent. A 5 year (%)
Chance score	50	50	50	50	50	50
0 - 1	-	-	-	-	-	-
1 - 2	60,8	78,3	56,6	89,1	70	-
2 - 3	53,3	86,6	90	95	100	-
3 - 4	81,6	85	90	96,6	100	91,6
4 - 5	74,1	80	86,6	93,3	100	-
5 - 6	76,6	88,3	93,3	91,6	90	96,6
6 - 7	88,3	87,5	88,3	84,1	85	83,3
> 7	83,3	85	83,3	93,3	90	100

Table 23: Median Matrix B1 score of the single age groups 1 year to 5 years after implantation
(from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Closed Set Sent. B1 pre (%)	Closed Set Sent. B1 ff* (%)	Closed Set Sent. B1 1m (%)	Closed Set Sent. B1 3m (%)	Closed Set Sent. B1 6m (%)
Chance score	33	33	33	33	33
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	-
2 - 3	-	-	-	-	-
3 - 4	-	-	-	-	100
4 - 5	-	-	-	81,1	86,6
5 - 6	-	-	-	100	92,7
6 - 7	-	-	98,8	88,8	52,2
> 7	93,3	97,7	88,8	94,4	93,3

* ff = first fitting

Table 24: Median Matrix B1 score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	Closed Set Sent. B1 1 year (%)	Closed Set ent. B1 1,5 year (%)	Closed Set Sent. B1 2 year (%)	Closed Set Sent. B1 3 year (%)	Closed Set Sent. B1 4 year (%)	Closed Set Sent. B1 5 year (%)
Chance score	33	33	33	33	33	33
0 - 1	-	-	-	-	-	-
1 - 2	-	-	72,2	-	93,3	100
2 - 3	-	55	90	100	100	-
3 - 4	96,1	78,3	82,2	88,8	93,8	97,7
4 - 5	98,8	93,3	88,8	87,7	96,6	100
5 - 6	81,1	88,8	96,1	94,4	90	93,3
6 - 7	77,7	83,3	84,4	90	100	-
> 7	86,6	87,7	82,7	83,3	86,1	100

Table 25: Median Matrix B2 score of the single age groups 1 year to 5 years after implantation
(from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Closed Set Sent. B2 pre (%)	Closed Set Sent. B2 ff* (%)	Closed Set Sent. B2 1m (%)	Closed Set Sent. B2 3m (%)	Closed Set Sent. B2 6m (%)
Chance score	33	33	33	33	33
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	-
2 - 3	-	-	-	-	-
3 - 4	-	-	-	-	95,8
4 - 5	-	-	-	-	80
5 - 6	-	-	-	-	100
6 - 7	-	-	84,1	78,3	100
> 7	92,9	75	61,6	82,5	87,5

* ff = first fitting

Table 26: Median Matrix B2 score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	Closed Set Sent. B2 1 year (%)	Closed Set Sent. B2 1,5 year (%)	Closed Set Sent. B2 2 year (%)	Closed Set Sent. B2 3 year (%)	Closed Set Sent. B2 4 year (%)	Closed Set Sent. B2 5 year (%)
Chance score	33	33	33	33	33	33
0 - 1	-	-	-	-	-	-
1 - 2	-	-	-	-	-	-
2 - 3	-	-	-	97,0	-	-
3 - 4	-	-	41,2	72,5	86,6	98,3
4 - 5	81,6	-	92,0	100	100	-
5 - 6	78,3	-	90	85	88,3	87,5
6 - 7	100	-	96,6	96,2	100	-
> 7	90,4	-	89,1	88,3	83,3	100

Table 27: Median Matrix C score of the single age groups 1 year to 5 years after implantation
(from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Closed Set Sent. C pre (%)	Closed Set Sent. C ff* (%)	Closed Set Sent. C 1m (%)	Closed Set Sent. C 3m (%)	Closed Set Sent. C 6m (%)
Chance score	25	25	25	25	25
0 - 1	-	-	-	-	-
1 - 2	-	-	-	-	-
2 - 3	-	-	-	-	-
3 - 4	-	-	-	-	-
4 - 5	-	-	-	-	70
5 - 6	-	-	-	-	97,5
6 - 7	-	-	97,5	-	100
> 7	87,5	77,0	51,6	90,4	93,3

* ff = first fitting

Table 28: Median Matrix C score of the single age groups 1 year to 5 years after implantation
(from one year to five years after implantation)

Age group (y) at time of implantation	Closed Set Sent. C 1 year (%)	Closed Set Sent. C 1,5 year (%)	Closed Set Sent. C 2 year (%)	Closed Set Sent. C 3 year (%)	Closed Set Sent. C 4 year (%)	Closed Set Sent. C 5 year (%)
Chance score	25	25	25	25	25	25
0 – 1	-	-	-	-	-	-
1 – 2	-	-	-	-	-	-
2 – 3	-	-	49,1	81,6	-	-
3 – 4	-	-	98,3	-	-	96,2
4 – 5	95	87,5	75,4	86,6	100	-
5 – 6	92,5	100	85,8	83,3	92,5	82,5
6 – 7	100	100	76,6	94,1	100	-
> 7	90,8	95,4	98,3	97,9	100	100

Monosyllable Open-Set Test

Schneider et al [5] also developed an open-set monosyllabic word test. This test contains two lists with ten words in each. The words have a CVC structure and the lists are equally weighted in terms of phoneme distribution. None of the words from the closed-set monosyllable list included in the EARS battery appears in this set of words. Two scores can be obtained, one for correct number of phonemes identified and one for correct number of words identified.

Table 29: Median Open-set words: Phoneme score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Open Set PH. Pre (%)	Open Set PH. ff* (%)	Open Set PH. 1m (%)	Open Set PH. 3m (%)	Open Set PH. 6m (%)
Chance score	9	9	9	9	9
0 – 1	-	-	-	-	-
1 – 2	0	-	-	3,3	38,7
2 – 3	0	-	0	0	31,6
3 – 4	0	60	14	20	46,6
4 – 5	0	-	10	28	36,3
5 – 6	0	-	25,8	33,3	45
6 – 7	0	63,7	56,6	50	46,6
> 7	0	31,2	38	40	60

* ff = first fitting

Table 30: Median Open-set words: Phoneme score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	Open Set W. PH. 1 year (%)	Open Set W. PH. 1,5 years (%)	Open Set W. PH. 2 years (%)	Open Set W. PH. 3 years (%)	Open Set W. PH. 4 years (%)	Open Set W. PH. 5 years (%)
Chance score	9	9	9	9	9	9
0 – 1	-	100	96,6	-	-	-
1 – 2	66,2	70	84,1	77,5	73,3	100
2 – 3	65	70	85,4	85,8	95,8	-
3 – 4	63,3	73,3	73,3	82,9	90	90
4 – 5	60	68,75	81,2	91,2	90	93,3
5 – 6	63,3	63,3	76,6	76,6	73,3	93,3
6 – 7	70	80	77,0	87,5	60,8	52,5
> 7	64,1	61,6	70	73,3	70	77,0

Table 31: Median Open-set Words: Word Score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Open Set W. pre (%)	Open Set W. ff* (%)	Open Set W. 1m (%)	Open Set W. 3m (%)	Open Set W. 6m (%)
Chance score	0	0	0	0	0
0 - 1	-	-	-	-	-
1 - 2	-	-	-	0	0
2 - 3	0	-	0	0	0
3 - 4	25	30	0	0	0
4 - 5	0	-	0	0	0
5 - 6	0	-	0	0	10
6 - 7	10	25	0	0	10
> 7	10	0	10	10	25

* ff = first fitting

Table 32: Median Open-set Words: Word score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	Open Set W. W. 1 year (%)	Open Set W. W. 1,5 years (%)	Open Set W. W. 2 years (%)	Open Set W. W. 3 years (%)	Open Set W. W. 4 years (%)	Open Set W. W. 5 years (%)
Chance score	0	0	0	0	0	0
0 - 1	-	100	90	-	-	-
1 - 2	30	40	60	50	40	100
2 - 3	20	30	60	65	85	-
3 - 4	10	40	30	50	80	80
4 - 5	20	40	50	75	80	80
5 - 6	30	30	40	40	60	80
6 - 7	30	40	45	75	35	35
> 7	30	30	40	45	70	60

Glendonald Auditory Screening Procedure (GASP)

Erber [6] developed the Glendonald Auditory Screening Procedure (GASP). This test was advantageous to include in EARS, as it had already been applied to children with CIs. It also uses only one kind of sentence structure (questions). This is useful as children may become confused when faced with different sentence structures (questions, commands or statements) in the same test. Children are allowed to either repeat the question or answer it.

Table 33: Median GASP score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	Open Set Sent. pre (%)	Open Set Sent. ff* (%)	Open Set Sent. 1m (%)	Open Set Sent. 3m (%)	Open Set Sent. 6m (%)
Chance score	0	0	0	0	0
0 – 1	-	-	-	-	-
1 – 2	-	-	-	-	0
2 – 3	0	-	-	0	10
3 – 4	20	30	0	60	0
4 – 5	0	-	0	0	10
5 – 6	0	-	-	40	15
6 – 7	-	45	70	40	40
> 7	40	20	50	50	60

* ff = first fitting

Table 34: Median GASP score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	Open Set Sent. 1 year (%)	Open Set Sent. 1,5 years (%)	Open Set Sent. 2 years (%)	Open Set Sent. 3 years (%)	Open Set Sent. 4 years (%)	Open Set Sent. 5 years (%)
Chance score	0	0	0	0	0	0
0 – 1	-	30	60	-	-	-
1 – 2	50	40	40	60	95	90
2 – 3	20	40	60	80	100	-
3 – 4	30	35	50	65	90	95
4 – 5	20	40	45	75	90	100
5 – 6	10	20	55	60	90	80
6 – 7	30	30	40	75	80	40
> 7	50	55	60	70	95	70

Meaningful Auditory Integration Scale (MAIS)

The MAIS [7] was developed as a measure of speech understanding in everyday situations as there is often a discrepancy between a child's performance on structured auditory tests and listening behaviours observed in their natural environment.

The MAIS was developed to evaluate meaningful use of sound in everyday situations. It provides information about attachment to the device, consistency of device use and response to sound in everyday listening situations. Results are scored as never, sometimes or always. For the purpose of this study scores were obtained by parents and teachers.

Table 35: Median MAIS Parent Scale score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MAIS parents pre (%)	MAIS parents ff* (%)	MAIS parents 1m (%)	MAIS parents 3m (%)	MAIS parents 6m (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	-	-	-	52,5	71,2
1 – 2	5		30	50	68,7
2 – 3	10	38,75	27,5	57,5	72,5
3 – 4	10		40	62,5	72,5
4 – 5	12,5	31,25	40	60	82,5
5 – 6	20	65	51,2	68,7	80
6 – 7	10		32,5	72,	78,7
> 7	37,5	17,5	67,5	80	80

* ff = first fitting

Table 36: Median MAIS Parent Scale score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MAIS parents 1 year (%)	MAIS parents 1,5 years (%)	MAIS parents 2 years (%)	MAIS parents 3 years (%)	MAIS parents 4 years (%)	MAIS parents 5 years (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	100	100	-	-	-	-
1 – 2	77,5	86,2	82,5	100	92,5	90
2 – 3	87,5	87,5	93,7	92,5	91,2	97,5
3 – 4	83,7	85	92,5	97,5	96,2	87,5
4 – 5	82,5	90	97,5	97,5	100	-
5 – 6	85	92,5	95	90	92,5	92,5
6 – 7	87,5	82,5	95	98,75	100	100
> 7	87,5	82,5	85	92,5	92,5	91,2

Table 37: Median MAIS Teacher Scale score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MAIS teacher pre (%)	MAIS teacher ff* (%)	MAIS teacher 1m (%)	MAIS teacher 3m (%)	MAIS teacher 6m (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	-	-	-	-	72,5
1 – 2	15	-	35	38,7	60
2 – 3	10	-	10	30	55
3 – 4	10	-	43,7	40	65
4 – 5	12,5	-	17,5	51,2	60
5 – 6	25	-	16,2	55	68,7
6 – 7	5	-	8,75	57,5	56,2
> 7	30	32,5	32,5	61,2	67,5

* ff = first fitting

Meaningful Use of Speech Scale (MUSS)

Robbins and Osberger [8] developed the MUSS, which is administered in a parental interview, thus making the assessment procedure easier. The MUSS is designed to assess the child's use of speech in different natural contexts.

The MUSS has ten probes which assess three areas of spoken language:

- 1) volitional control of speech,
- 2) use of speech alone, and
- 3) the child's ability to modify his speech to increase comprehension of his message by a listener.

Parents and teachers were asked to assess children using the MUSS for this study.

Table 38: Median MAIS Teacher Scale score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MAIS teacher 1 year (%)	MAIS teacher 1,5 years (%)	MAIS teacher 2 years (%)	MAIS teacher 3 years (%)	MAIS teacher 4 years (%)	MAIS teacher 5 years (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	92,5	95	-	-	-	-
1 – 2	75	80	85	87,5	90	80
2 – 3	75	83,7	83,7	82,5	85	-
3 – 4	72,5	82,5	80	87,5	92,5	87,5
4 – 5	70	87,5	85	100	100	-
5 – 6	82,5	72,5	71,2	90	83,7	100
6 – 7	70	76,2	83,7	-	-	-
> 7	75	75	77,5	87,5	88,7	88,7

Table 39: Median MUSS Parent Scale score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MUSS parents pre (%)	MUSS parents ff* (%)	MUSS parents 1m (%)	MUSS parents 3m (%)	MUSS parents 6m (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	-	-	-	-	-
1 – 2	20	-	20	27,5	40
2 – 3	17,5	0	21,2	27,5	38,7
3 – 4	21,2	-	22,5	30	40
4 – 5	20	46,2	21,2	40	47,5
5 – 6	22,5	15	32,5	42,5	47,5
6 – 7	18,7	-	28,7	45	52,5
> 7	65	62,5	65	72,5	75

* ff = first fitting

Table 40: Median MUSS Parent Scale score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MUSS parents 1 year (%)	MUSS parents 1,5 years (%)	MUSS parents 2 years (%)	MUSS parents 3 years (%)	MUSS parents 4 years (%)	MUSS parents 5 years (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	85	82,5	-	-	-	-
1 – 2	52,5	77,5	78,7	87,5	92,5	-
2 – 3	56,2	67,5	77,5	88,7	97,5	-
3 – 4	45	67,5	82,5	86,2	92,5	87,5
4 – 5	57,5	80	86,2	87,5	91,2	-
5 – 6	55	62,5	76,2	82,5	85	95
6 – 7	60	55	70	42,5	95	95
> 7	75	77,5	86,25	87,5	91,2	82,5

Table 41: Median MUSS Teacher Scale score of the single age groups 1 year to 5 years after implantation (from the pre-operative test interval to six months after implantation)

Age group (y) at time of implantation	MUSS teacher pre (%)	MUSS teacher ff* (%)	MUSS teacher 1m (%)	MUSS teacher 3m (%)	MUSS teacher 6m (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	-	-	-	-	-
1 – 2	12,5	-	13,7	20	32,5
2 – 3	7,5	-	12,5	22,5	25
3 – 4	15	-	26,2	28,7	30
4 – 5	21,2	-	42,5	30	50
5 – 6	37,5	-	17,5	32,5	45
6 – 7	32,5	-	22,5	32,5	26,2
> 7	62,5	-	57,5	70	70

* ff = first fitting

Table 42: Median MUSS Teacher Scale score of the single age groups 1 year to 5 years after implantation (from one year to five years after implantation)

Age group (y) at time of implantation	MUSS teacher 1 year (%)	MUSS teacher 1,5 years (%)	MUSS teacher 2 years (%)	MUSS teacher 3 years (%)	MUSS teacher 4 years (%)	MUSS teacher 5 years (%)
Chance score	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
0 – 1	80	90	-	-	-	-
1 – 2	60	51,2	58,7	75	75	-
2 – 3	52,5	67,5	62,5	81,2	87,5	-
3 – 4	52,5	67,5	77,5	88,7	77,5	77,5
4 – 5	52,5	72,5	80	93,7	100	-
5 – 6	62,5	61,2	62,5	75	75	87,5
6 – 7	67,5	45	56,2	-	-	-
> 7	80	75	67,5	91,25	83,7	80

Conclusion

It is the aim of the EARS assessment tool to track progress of auditory perception over time in children with CIs. The tool can assess children within and across languages. It is suitable for children between 3 and 18 years of age who have diversity in linguistic and auditory capabilities. Clinicians may use the norm tables to estimate the degree to which an individual child is making expected auditory progress with his CI. According to the scores listed, decisions can be made on a child's therapeutic needs and progress. These data can be considered as benchmarks and may be useful in parent counselling.

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