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Normative data of the A§E® discrimination and identification tests in preverbal children

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ABSTRACT *The A§E® is a set of suprathreshold tests for the auditory evaluation of the hearing impaired. A particular population of interest is the hearing-impaired preverbal child. This paper reports on normative data of the A§E® discrimination test in children aged 10 months and of the A§E® identification tests in children aged 2 to 4 years. Normally hearing children of these ages were tested and pass criteria were defined in such a way that 95% of the hearing infants would pass the tests. With these criteria, the A§E® discrimination test is feasible at 10 months of age and the A§E® identification test from 30 months of age.*

Keywords: A§E; auditory speech sounds evaluation; suprathreshold test; hearing impaired infant; preverbal

Introduction

As described in the previous paper (Govaerts et al. 2006), the A§E® was developed to evaluate the suprathreshold hearing of hearing-impaired people, and especially of hearing-impaired preverbal children. As outlined, the preverbal stage of hearing-impaired children may typically last till the age of 4–5 years. Since the results on audiological tests at these young ages not only depend on the level of hearing impairment, but also on several developmental factors, new tests require normative data. These data are obtained from hearing infants of this same age group.

Conventional discrimination tests are not really suited for the preverbal child. They are known to be boring and cognitively demanding (Boothroyd 1997) and they are not feasible below the age of 3 years or even later in hearing-impaired children (Daemers K et al., oral communication, 3rd European Conference on Audiology, Prague, 1997; De Sloovere M et al., oral communication, 4th European Symposium on Paediatric Cochlear Implantation, 's-Hertogenbosch, 1998). Even when conventional discrimination tests are modified for the younger children to

visually reinforced discrimination audiometry, only some are feasible (Eilers et al., 1977; Moore 1995; Dawson et al., 1998).

Identification tests in clinical practice are feasible in children from 3.5 to 4 years onwards, provided that adequate test material is used (Jerger and Jerger, 1982; Hodgson 1994). Play audiometry, which is a detection test requiring active responses from the child, is feasible at younger ages. It has been shown that 70% of children between 2 and 2.5 years, and 90% of those between 2.5 and 3 years are capable of doing play audiometry. The discrepancy in feasibility between the detection test and identification tests is due to the dependence of identificaton tests on the language development and cognitive skills of the child. It could be speculated that a speech sound identification test is less demanding in terms of linguistic skills and that the lower age limit for the feasibility would be lower than for classical identification tests.

The authors have experienced that the A§E® discrimination test is feasible from as young as 10 months of age and the A§E identification tests from 2–3 years of age. This paper describes the first normative data obtained for both tests at these young ages.

Subjects and methods

A§E® discrimination test

The A§E® discrimination test was carried out in 30 hearing infants aged 10 months (average 10.4 months, range 9.4–12.8 months). All children had hearing thresholds of 20 dB or better at 500, 1000 and 2000 Hz with presence of transient evoked otoacoustic emissions. All children were evaluated for the 22 speech sound pairs (Table 1). On average this took three sessions (range 2–5) spread over 5 weeks (range 1–13 weeks). Each speech sound pair took approximately 6 min to be assessed. All speech sounds were presented in free field at an intensity of 70 dB HL (re 1 kHz narrow band noise), with the loudspeaker positioned at 1 m from the child on either the left or the right side.

The children were tested by two experienced paediatric audiologists (tester and distracter) in a soundproof testing booth. The infant was sitting in a seat with their caregiver (mostly the mother) sitting behind but not touching the child. The primary reaction that was looked for in the infant was a head turn, although the audiologists were allowed to judge other reactions as orientation reflexes. Only if both audiologists agreed in their judgement, was a positive reaction scored. Visual reinforcement was used to reward the infant both during the conditioning and the test procedure (Eilers et al., 1977). The odd speech sound was presented eight times and the reaction was scored as positive (orientation reflex) or negative (no orientation reflex). In case of three consecutive positive responses, the test was discontinued. For each speech sound pair and for each infant, the number of orientation reflexes (on eight presentations) was calculated as well as the maximal

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Table 1: Decision criteria and results of the discrimination test

Speech sound pairs*	1/8	2/8	3/8	2 consecutive	3 consecutive
a–r	30	30	30	30	30
u–ʃ	30	30	30	30	30
u–i	30	30	30	30	27
i–a	30	30	30	30	26
u–a	30	30	30	30	29
o–a	30	30	30	29	23
u–o	30	30	30	28	24
ə–a	30	30	27	28	20
ə–u	28	26	24	23	15
ə–o	30	29	24	26	22
ɛ–a	30	30	27	29	19
i–ɛ	30	30	30	30	26
ə–ɛ	30	30	27	28	26
ə–i	30	26	21	24	17
y–i	27	24	23	22	17
u–y	28	28	25	26	22
z–s	29	27	23	26	19
m–f	30	30	30	30	26
m–z	30	30	30	29	26
m–r	30	30	29	30	24
s–ʃ	30	30	30	30	27
v–z	30	27	26	25	24

*See Govaerts et al. (2006). Each field shows the number of infants (out of 30) that would pass the discrimination test for a given speech sound pair if the decision criterion defined at the top of each column was used. The following decision criteria were evaluated: 1/8, 2/8 and 3/8: one, two or three correct reflexes on eight presentations; two and three consecutive: a maximal number of two or three consecutive reflexes in the series of eight. For instance, for /y/–/i/ discrimination, 27 children showed at least one correct reflex, 24 children at least two and 23 at least three, 22 had two consecutive reflexes and 17 had three consecutive reflexes in the series of eight presentations. The black fields represent the speech sound pairs of the 'minimal set', see text. All phonetic symbols are according to the International Phonetic Alphabet (IPA); see www2.arts.gla.ac.uk/IPA/sounds.html.

number of consecutive orientation reflexes. For example, a child that showed the following reactions to the eight presentations of the odd speech sound:

no – no – reflex – no – reflex – reflex – no – reflex

would score four reflexes out of eight and a maximal of two consecutive reflexes. Then several decision criteria were evaluated in terms of how many of these 30

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hearing children would pass the discrimination test when a given decision criterion would be used.

A§E® identification test

Normative data for the speech sound identification test of the A§E® were obtained from two groups: (1) 30 hearing children aged 2.5 years (average 28 months, range 25–30 months); and (2) 30 hearing children aged 3.5 years (median 43 months, range 37–47 months). All children were evaluated for the ten sets of speech sounds (see Figure 6 of Govaerts et al. 2006). The number of presentations of each speech sound was five for two-choice tests, four for three-choice tests and three for five- and six-choice tests. All speech sounds were presented in free field at an intensity of 70 dB HL (re 1 kHz narrow band noise) with the loudspeaker positioned at 1 m in front of the child. The children were tested by one audiologist in a quiet room. The response was a forced picture-pointing response (see test procedure and Figures 4 and 5 of Govaerts et al. 2006). For each set of speech sounds, the number of children that showed an identification score above the statistical significance level was calculated. Also, the average score on each set of speech sounds was compared to the significance level of that set. In order to find a possible age effect, a linear regression analysis was performed between the age at which the A§E® speech sound identification test was taken and the number of speech sound sets that were identified above the level of significance.

Results

A§E® discrimination test

The decision criteria and the results are shown in Table 1. Based on these results, the speech sound pairs can be ordered with respect to the ease or the difficulty with which infants react to the difference. This is shown in Table 2. In consequence, if the discrimination of a speech sound pair is tested, Table 2 gives the decision criteria that would yield a 'pass' in hearing children.

A§E® identification test

The results are given in Tables 3 and 4. The result of the linear regression analysis is shown in Figure 1.

Discussion

These normative data show that it is feasible to use the speech sound discrimination test of the A§E® in infants as young as 10 months. In daily practice, even younger infants (6–7 months) have been tested with success. Some speech sound pairs appear to be 'easier' than other pairs to elicit good orientation reflexes from

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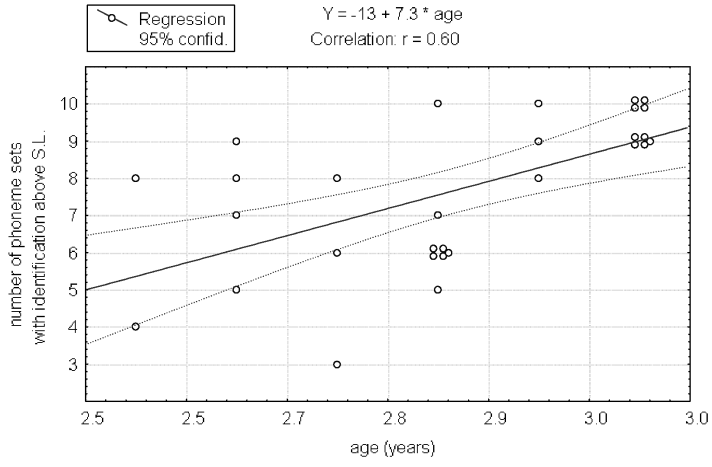

Figure 1: Linear regression between the age at which the A§E® speech sound identification test was taken and the number of speech sound sets that were identified above the level of significance. It can be inferred that at the age of 2.5 years, approximately five to six sets (out of ten, see Figure 6 of Govaerts et al. 2006) are well identified by hearing children. At the age of 3 years, this has gone up to approximately nine sets out of ten.

the infant. Therefore different 'pass criteria' may be used for different speech sound pairs (Table 2). However, testing infants of such a young age is seldom a matter of solid test circumstances and robust statistical interpretation, but rather of good judgement by experienced testers. Thus the pass criteria of Table 2 should not be used too strictly but should provide some guidance to the testers. In addition, testing these young infants requires a lot of time, which may not always be available. Therefore a 'minimal set' of speech sound pairs is suggested. This is an arbitrary selection of seven speech sound pairs (see Tables 1 and 2) in which the cardinal vowels are represented, as well as contrasts in voicing (/z/–/s/), place of articulation (/s/–/ʃ/ and /v/–/z/) or combinations (/m/–/z/) (all phonetic symbols are according to the International Phonetic Alphabet (IPA); see www2.arts.gla.ac.uk/IPA/sounds.html). As can be seen in Table 2, the seven speech sound pairs of the minimal set are also well distributed over the hierarchical scale. The minimal set can often be assessed in a single test session even for the very young infants.

The results on the identification tests show that /z/–/s/ and /m/–/l/–/v/ are very difficult tests even for the older children. No more than roughly 60% of the 3.5-year-old children can perform them. The other identification tests yield significant results in 67 to 97% of hearing 2.5-year-old children and in 87 to 100% of hearing 3.5-year-old children. These figures are in the range of the earlier-mentioned results in play audiometry and they are better than classical identification tests. Still, for the 2.5-year-old group, only the scores on /a/–/i/–/u/ and on /m/–/r/–/v/–/f/–/s/–/z/ are above the significance level in 95% of the children. This means that the score on the identification test in this age group has only a positive predictive

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Table 2: Hierarchy of the speech sound pairs in order of ease of discrimination

Decision criterion that is met by 95% of the children	Speech sound pair*
3 in total with 3 consecutives	a–r
	u–ʃ
	u–a
3 in total with 2 consecutives	u–i
	i–a
	o–a
	i–ɛ
	m–f
	m–z
	m–r
	s–ʃ
2 in total with 2 consecutives	ɛ–a
2 in total	u–o
	ə–a
	ə–o
	ə–ɛ
1 response	ə–i
	z–s
	v–z
No response	ə–u

*See Govaerts et al. (2006). The upper speech sound pairs are most easily discriminated by the infant. For instance, in all infants, three consecutive orientation reflexes can be elicited in a series of eight presentations of the odd speech sound /r/ against a background of /a/. The black fields represent the speech sound pairs of the 'minimal set', see text.

value. Indeed, if a child achieves a score above the significance level, one may conclude that the identification of the given speech sounds is OK. Roughly two out of three children of this age will be capable of doing this. On the other hand, if the score stays below the significance level, one is not entitled to conclude that the identification is not OK. It is remarkable to note the influence of the age on the results, even within the limited age range of the test group (25–30 months). Figure 1 gives the linear regression line and its 95% confidence interval and this shows a statistically significant age effect ($p < 0.001$). Table 5 shows the sets of speech sounds that were well identified by all 2.5-year-old children ($n = 10$). This is in line with the findings in the 3.5-year-old group (Table 4). In consequence, it can be concluded that there is a transition zone that lies somewhere around 2.5

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Table 3: Normative data of the identification test (2.5-year-old group)

	a–r	z–s	a–i–u	m–r–v	m–r–v–f–s–z	f–s–ʃ	a–m	m–l–v	a–i–u	a–i–ɛ–u–o
% children	67	37	83	70	93	77	70	57	97	90
Score	9.0	7.3	9.1	8.8	10.1	8.5	9.1	8.6	10.8	10.0
(S.D.)	(1.3)	(2.3)	(2.0)	(2.7)	(2.1)	(1.7)	(1.5)	(3.0)	(1.4)	(2.7)
P5	6.9	3.5	5.8	4.4	6.6	5.7	6.6	3.7	8.5	5.6
SL	8.1	8.1	7.2	7.2	6.1	7.2	8.1	7.2	7.2	6.0

The columns represent the sets of speech sounds. % children: the percentage of the children with statistically significant identification ($p < 0.05$); Score: the average score (+ standard deviation) of the children on the set of speech sounds; P5: the 5th percentile as calculated from the average and standard deviation; SL significance level above which the score has to be to conclude that the speech sounds are identified in a significant way. Grey fields: identification tests with significant results in more than 95% of the hearing test population.

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Table 4: Normative data of the identification test (3.5-year-old group)

	a–r	z–s	a–i–u	m–r–v	m–r–v–f–s–z	f–s–ʃ	a–m	m–l–v	a–i–u	a–i–ɛ–u–o
% children	97	57	100	90	100	87	93	63	100	93
Score	9.9	8.3	11.3	10.4	13.0	9.5	9.5	8.4	11.0	10.2
(S.D.)	(0.4)	(1.7)	(1.2)	(1.8)	(2.0)	(1.8)	(0.8)	(2.3)	(1.1)	(2.3)
P5	9.2	5.5	9.3	7.4	9.7	6.5	8.2	4.6	9.2	6.4
SL	8.1	8.1	7.2	7.2	6.1	7.2	8.1	7.2	7.2	6.0

See Table 4 for legend.

Table 5: Sets of speech sounds that are identified by all* hearing children of 30 months	
Identified by all	Not identified by all
a–r	z–s
a–i–u	f–s–ʃ
(onomatopoeia)	
m–r–v	m–l–v
m–r–v–f–s–z	
a–m	
a–i–u (mouth images)	
a–i–ɛ–u–o	
* $n = 10$.	

years. Before this age, the speech sound identification test of the A§E® can only be interpreted in a positive direction. Only some of these children (between 67 and 97%) will perform well. Beyond this age, all speech sound tests, except /z/–/s/ and /m/–/l/–/v/ and /f/–/s/–/ʃ/can be used in both directions. All children should perform well at this age.

In conclusion, the A§E® discrimination test can be used from the age of 10 months. At this age, the pass criteria of Table 2 should be used as guidelines. The A§E® identification test can be used from the age of 2 years onwards. Between 2 and 2.5 years, only the /a/–/I/–/u/ with mouth images and four presentations should be used and only positive results should be withheld. Between 2.5 and 3.5 years of age, all the tests of the first column of Table 5 can be used.

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