

# INFLUENCE OF LACK OF AUDITORY SPEECH PERCEPTION ON SOUND PRODUCTIONS OF DEAF INFANTS \*

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## Abstract

This study is a first report of a combination of two linked projects. Sound productions of deaf and hearing children were studied longitudinally from 2.5 until 18 months of age in order to establish in which respect the sound productions of deaf children are influenced by lack of auditory perception. Differences between deaf and hearing children were found in number of spoken utterances and in type of articulation and phonation. Results indicate that children's sound productions are influenced by auditory perception from a very early age onwards and that from about 9 months onwards differences in utterance types are quite obvious.

## 1 Introduction

Many literature has reported about the differences in speech development of deaf children. The speech development of deaf children seems to differ from that of hearing children already at an early age. To summarize, differences have been found in the number of spoken utterances (e.g. Clement et al., 1994, 1995; Oller et al., 1985; Spencer, 1993), utterance duration (e.g. Clement et al., 1996; Ryalls & Larouche, 1992), the start of babbling (e.g. Oller & Eilers, 1988), articulation characteristics (e.g. Clement et al., 1994, 1995; Kent et al., 1985; Stoel-Gammon, 1988), and spectral characteristics (e.g. Kent et al., 1987; Ryalls & Larouche, 1992). The role of a more or less adequately functioning audition in this development is an important aspect in the study of early speech development

As far as we know no systematic longitudinal study has been performed on acoustical and perceptual characteristics of the vocalizations of deaf children starting within the first half year of life. The present study, which is a combination of parts of two larger projects, reports on longitudinal data from six deaf and six hearing children

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between 2.5 (or somewhat older) and 18 months of age. The larger projects are carried out by two researchers. The first project contains the age period from 2.5 until 11.5 months and is studied by Chris Clement. The second project contains the following age period from 12.5 until 17.5 months and is studied by Ineke van den Dikkenberg. In the present study the data of the two projects are combined, so we can publish results from the whole age period from 2.5 until 18 months. The main questions we address in the present study are: in which respect are the sound productions of deaf children influenced by lack of auditory perception? Which are the acoustical and perceptual differences and similarities in the speech sound productions of young deaf and hearing children?

## 2 Method

### 2.1 Subjects

Twelve mother-child pairs participated in the study: six children (5 boys, 1 girl) in the profoundly hearing impaired group (group HI) and six matched children (5 boys, 1 girl) in the normally hearing group (group NH). Specific information of the hearing status of the deaf children is shown in table 1. The NH children were matched with the HI children on several criteria (see Clement & Koopmans-van Beinum, 1995). All NH children were recorded from the age of 2.5 months onwards. Recordings of the deaf children started as soon as possible after the hearing loss was detected. Two HI children were recorded from the age of 2.5 months, one from 3.5 months and three from the age of 5.5 months onwards. Two mother-child pairs (one HI child (HI-6) and one NH child, both girls) were excluded from the age period from 12.5 until 18 months because of some problems with the continuity of the recordings.

Table 1. Characteristics of the hearing impaired children (see also Clement & Koopmans-van Beinum, 1995).

Subject	Hearing loss best ear (dB)	Loss with hearing aids (dB)	Age at diagnosis (months)	Hearing aids from age (months)	Language method *	Start of recordings (months)
HI-1	97	55	1.5	2.0	Oral	2.5
HI-2	93	55	3.0	3.5	TC	5.5
HI-3	110	65	4.0	4.5	Oral/TC	5.5
HI-4	>120	not tested	0.5	-	NGT/TC	2.5
HI-5	120	not tested	3.0	6.5	NGT/TC	3.5
HI-6	>100	>100	5.0	7.5	TC	5.5

\* Oral = Oral language method, TC = Total Communication, NGT = Dutch Sign Language

### 2.2 Data collection

Audio recordings of 30 minutes of mother-child interaction were made every two weeks from the age of 2.5 months and monthly from the age of 12.5 months onwards (see Clement et al., 1994). From every monthly audio recording all mother and child

utterances were transcribed during the first 10 minutes (or if necessary another selected 10-minutes period in which the communication between mother and child was as optimal as possible). An utterance was defined as a sound production during one breath cycle starting with inspiration. Vegetative sounds, laughing, and crying are not taken into account. These selected 10 minutes form the basis for our analyses (see also Clement et al. 1994, 1995; Van den Dikkenberg-Pot et al., 1997, to appear).

### 2.3 Analysis procedures

Acoustical and perceptual analyses were performed for each child per monthly recording on 50 utterances evenly selected out of these ten minutes. All utterances were digitized with a sample frequency of 48 kHz and stored for further analysis.

To make a comparison possible between our results and those found in the literature we decided to investigate, among other things, the same aspects of the speech sounds of the children as have been mentioned in the literature. In this study, these aspects concern the number of spoken utterances, utterance duration, F0 measurements and articulation characteristics.

#### *Number of spoken utterances, utterance duration, and F0 measurements*

Total number of spoken utterances of each child during the selected 10 minutes of every monthly recording were counted. Utterance duration was measured in ms if possible on positive zero-crossings for all 50 selected utterances per monthly recording.

F0 measurements consisted of measuring mean F0, median F0, range and minimum and maximum values and were performed with the help of an autocorrelation algorithm in the program Praat (Boersma, 1993) (see also Clement et al., 1996). To avoid the influence of strong deviant values, in this study we addressed the median F0 values. To make comparison with literature possible we used the measuring quantity Hz.

#### *Classification of types of articulation and types of phonation*

Description of the articulation characteristics can be divided into the classification of types of articulation and phonation and the description of place and manner of articulation. This study reports about the classification of the types of articulation and types of phonation. The description of place and manner of articulation will be performed in the near future.

We found no literature yet which reported about the types of articulation and phonation in the utterances of deaf children. The method used here has been based on an earlier study on infant speech development of Koopmans-van Beinum & Van der Stelt (1986). They used a sensori-motor description of speech movements based on the source-filter model of speech production to describe early infant vocalizations. Each selected utterance was classified into three possible types of articulation and five possible types of phonation. Describing the utterances of the children in this way gives us the opportunity to look at the influence of the audition in combining the two sources of speech sound production in infants, namely the larynx and the vocal tract.

The following three articulation types and five phonation types were possible: (Clement et al., 1994, 1995):

#### Types of articulation:

- NoArt no articulatory movement
- OneArt one articulatory movement
- TwoArt two or more articulatory movements during two- or more-syllabic utterances (e.g. babbling)

#### Types of phonation:

- NoPhon no phonation
- UnIntPhon uninterrupted phonation
- IntPhon interrupted phonation
- VarUnIntPhon variegated uninterrupted phonation (variation in pitch, loudness or intonation)
- VarIntPhon variegated interrupted phonation

To combine these types of articulation and phonation we presented them in a matrix. In this matrix each cell represents a specific utterance type described by articulation and phonation characteristics.

The utterances from the age period from 2.5 until 11.5 months were classified by the researchers of both projects. The inter-judge agreement amounted more than 80%. The classification of the utterances from the age period from 12.5 until 17.5 months was performed by the researcher of the second project. To test the reliability of the classification of this listener, the material was classified twice by this listener. The intra-judge agreement was 93,7% for the articulation types and 89,3% for the phonation types.

## 3 Results

### 3.1 Number of spoken utterances

Number of spoken utterances were counted per child per recording. When calculating for all deaf and all hearing children the mean number of spoken utterances produced during the whole period, it turned out that the deaf children produced more spoken utterances than the hearing children until 18 months of age (HI mean = 116, sd. = 54, NH mean = 82, sd. = 36). A Mann Whitney U-test shows a significant difference between the two groups ( $p < 0.05$ ). To see more about the developmental aspects we calculated running averages over 3-months periods for all deaf and all hearing children. This is shown in figure 1. Table 2 gives related information to the graph of figure 1. From age 3.5-5.5 months until 10.5-12.5 months there was a significant difference in the number of spoken utterances produced by deaf and hearing children. After this period especially the deaf children decrease in their sound production. Since only audio-recordings were made until 18 months we have no data on their production of signs. A possible increase of signed utterances could (partly) contribute to this decrease in spoken utterances. The hearing children only slightly decrease in their production after this period. This could be caused by the fact that around this time they start producing their first spoken words. After a short period they again increase their sound production.

### Average number of spoken utterances

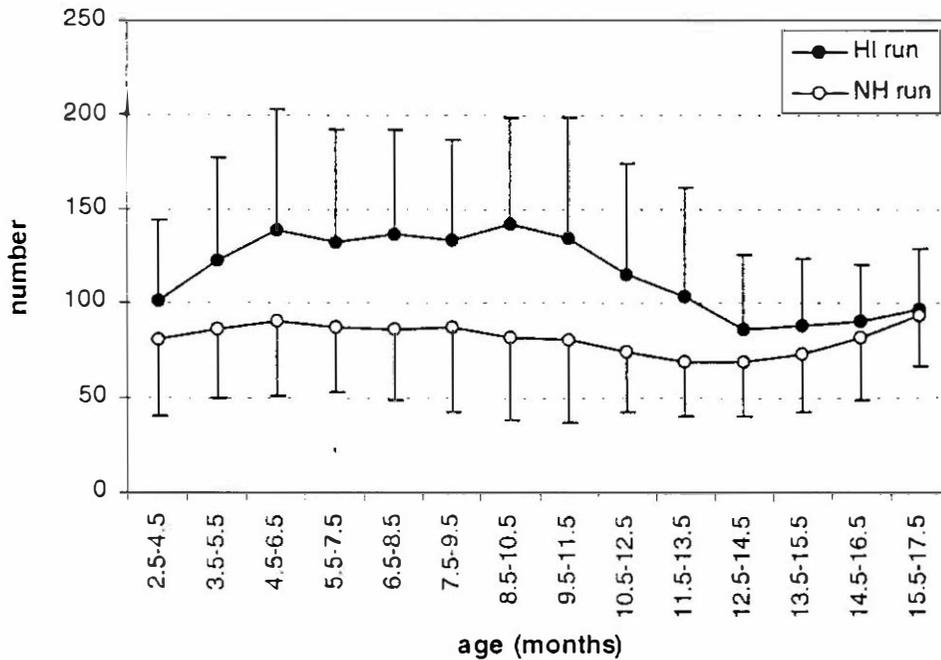


Figure 1. Running averages and standard deviations of the number of spoken utterances of the deaf and hearing children in the 10 minutes period. For the HI group n=8-18 and for the NH group n=15-18. (see table 2 for specific details)

Table 2. Presentation of the mean number of spoken utterances of deaf and hearing children. The table gives running averages over 3-months periods and standard deviations (sd.). Also for every period the number of deaf and hearing children is given (n) and the signficancy according to a Mann-Whitney U Test (p<.05).

age (months)	HI			NH			sign.
	n	average	sd.	n	average	sd.	
2.5-4.5	8	101.6	42.1	18	81.6	40.9	ns
3.5-5.5	12	122.9	54.9	18	86.4	36.1	<.044
4.5-6.5	15	139.1	64.0	18	90.8	39.2	<.022
5.5-7.5	18	132.5	59.5	18	87.2	33.8	<.009
6.5-8.5	18	136.9	54.9	18	86.1	36.6	<.004
7.5-9.5	18	133.7	53.7	18	87.3	44.9	<.007
8.5-10.5	18	141.7	56.9	18	82.3	43.8	<.003
9.5-11.5	18	134.3	64.7	18	81.2	44.1	<.016
10.5-12.5	17	115.4	59.0	17	74.3	31.1	<.038
11.5-13.5	16	104.1	57.1	16	69.9	29.0	ns
12.5-14.5	15	86.2	39.6	15	69.7	29.6	ns
13.5-15.5	15	88.3	36.0	15	73.8	31.3	ns
14.5-16.5	15	90.3	30.2	15	81.9	32.3	ns
15.5-17.5	15	97.1	31.8	15	94.1	27.1	ns
mean	80	115.7	53.8	88	82.1	35.5	<.001

### 3.2 Duration of the utterances

By computing the mean utterance duration of all deaf and all hearing children over the whole period, it turned out that the mean duration of the utterances of the deaf children is longer than for the hearing children (HI mean = 997 ms and sd. = 309 ms, NH mean = 883 ms and sd. = 284 ms). But according to a Mann Whitney U test there was no significant difference between the two groups ( $p > .05$ ). To look at some developmental aspects during the whole period running averages were counted over 3-months periods. Figure 2 shows the running averages of the utterance duration of all deaf and hearing children. Table 3 gives more detailed information about the number of children in every period, the average duration, the standard deviation and the level of significance according to a Mann-Whitney U Test. From the figure and the table it can be noticed that from age period 10.5-12.5 months until 14.5-16.5 months the deaf children produce significantly longer utterances than hearing children. In this same period hearing children start producing their first spoken words. Because these words often are one syllabic words this can be the cause of the temporary decrease in duration. The deaf children have in this same period an increase in utterance duration. They do not start producing spoken words yet, so their utterances remain simple in structure and have a longer duration.

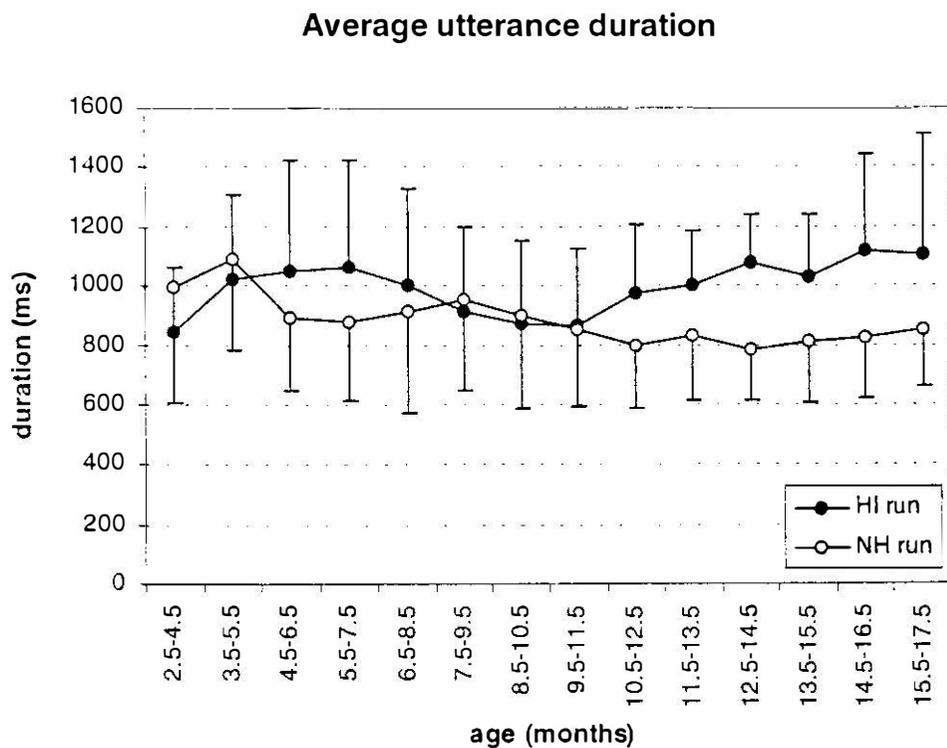


Figure 2. Running averages of the utterance duration in ms. and standard deviations of the selected utterances of the deaf and hearing children. For the HI group  $n=8-18$  and for the NH group  $n=15-18$ . (see table 3 for specific details)

Table 3. Presentation of the mean utterance duration in ms. of deaf and hearing children. The table gives running averages over 3-months periods and standard deviations (sd.). Also for every period the number of deaf and hearing children is given (n) and the significance according to a Mann-Whitney U Test ( $p < .05$ ).

age (months)	HI			NH			sign.
	n	average	sd.	n	average	sd.	
2.5-4.5	8	845.3	216.6	18	996.6	390.0	ns
3.5-5.5	12	1019.4	290.7	18	1089.2	303.1	ns
4.5-6.5	15	1049.8	376.4	18	889.9	246.3	ns
5.5-7.5	18	1064.2	362.1	18	876.2	260.9	ns
6.5-8.5	18	999.5	327.0	18	914.6	339.8	ns
7.5-9.5	18	913.9	283.4	18	953.1	304.5	ns
8.5-10.5	18	873.7	274.2	18	900.7	311.8	ns
9.5-11.5	18	864.6	261.1	18	848.6	256.9	ns
10.5-12.5	17	971.0	231.8	17	795.6	210.0	<.021
11.5-13.5	16	1000.3	185.2	16	827.3	217.4	<.018
12.5-14.5	15	1077.5	160.8	15	782.3	171.5	<.001
13.5-15.5	15	1027.7	208.6	15	810.0	206.0	<.011
14.5-16.5	15	1119.1	324.0	15	823.2	206.7	<.007
15.5-17.5	15	1106.3	408.1	15	853.0	195.2	ns
mean	80	996.7	308.5	88	883.3	283.6	<.007

### 3.4 Median F0

Calculating the mean values of the median F0 measurements of all deaf and all hearing children over the whole period resulted in a slightly higher median F0 value for the deaf children than for the hearing children (HI mean = 368 Hz and sd. = 79 Hz, NH mean = 355 Hz and sd. = 64 Hz). A Mann Whitney U-test showed that this difference was not significant ( $p > .05$ ). In order to study the development of these values running averages were counted over 3-months periods. These averages and the standard deviations are shown in figure 3. More detailed information about the results, like number of children per period (n), average values, standard deviations (sd) and level of significance according to a Mann-Whitney U Test, is given in table 4.

In figure 3 and table 4 it can be seen that the slightly higher F0 value of the deaf children is present only in the age period from 6.5-8.5 months until 11.5-13.5 months. At the other ages the F0 values of the deaf and hearing children are almost the same. At no age period the difference in F0 value between the two groups of children became significant.

### Average median F0 values

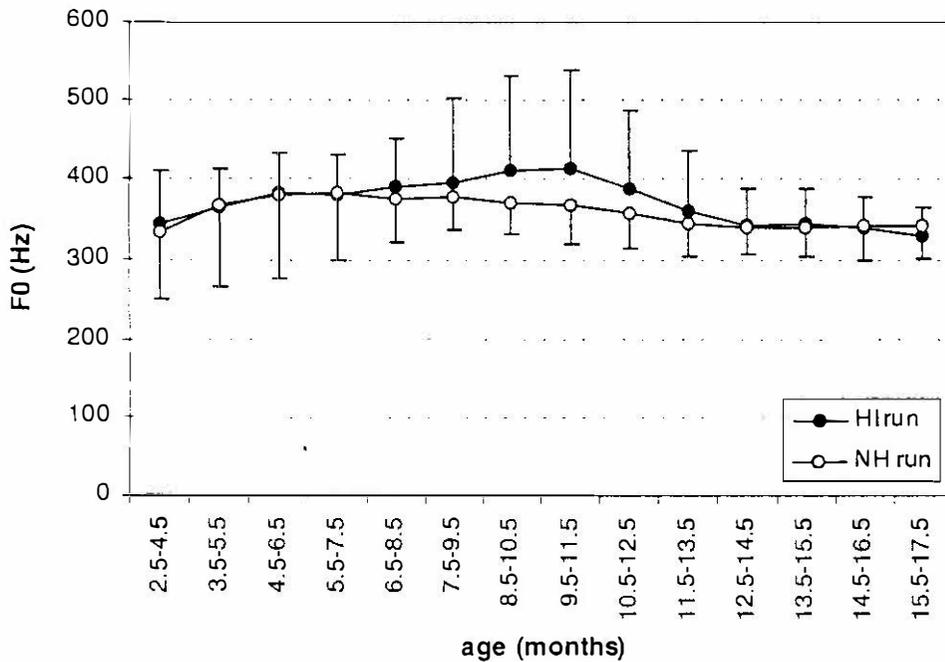


Figure 3. Running averages and standard deviations of the median F0 values in Hz of the selected utterances of the deaf and hearing children. n=8-18 for the HI group and n=15-18 for the NH group (see table 8 for more details).

Table 4. Presentation of the median F0 values in Hz of the deaf and hearing children. The table gives running averages over 3-months periods and standard deviations (sd.). Also for every period the number of deaf and hearing children is given (n) and the level of significance according to a Mann-Whitney U Test ( $p < .05$ ).

age (months)	HI			NH			sign.
	n	average	sd.	n	average	sd.	
2.5-4.5	8	344.4	66.7	18	334.6	83.8	ns
3.5-5.5	12	364.5	49.4	18	368.5	102.9	ns
4.5-6.5	15	383.9	49.2	18	380.9	104.3	ns
5.5-7.5	18	379.6	51.4	18	383.8	85.0	ns
6.5-8.5	18	389.9	61.4	18	374.7	54.2	ns
7.5-9.5	18	395.2	107.2	18	376.9	39.9	ns
8.5-10.5	18	411.4	119.5	18	369.6	37.7	ns
9.5-11.5	18	413.1	124.6	18	367.9	48.4	ns
10.5-12.5	17	387.5	100.1	17	358.6	45.5	ns
11.5-13.5	16	360.1	76.4	16	345.1	41.5	ns
12.5-14.5	15	342.8	45.8	15	338.6	32.6	ns
13.5-15.5	15	344.5	43.9	15	340.3	35.7	ns
14.5-16.5	15	338.4	40.6	15	341.9	42.8	ns
15.5-17.5	15	329.4	36.1	15	341.9	40.4	ns
mean	80	368.5	79.2	88	354.9	63.7	ns

### 3.3 Type of articulation and phonation

Results of the combination of the articulation and phonation types are given in table 5. In this table the mean number of articulation and phonation types over the whole period for all deaf and all hearing children is presented. Significant differences between the two groups of children are shown in bold (Mann-Whitney U test,  $p < .05$ ).

Table 5. Mean number of the articulation and phonation types per month for deaf and hearing children. Shaded areas show significant differences between the two groups (Mann-Whitney U Test,  $p < .05$ ).

Types of phonation	Types of articulation							
	NoArt		OneArt		TwoArt		Total	
	HI	NH	HI	NH	HI	NH	HI	NH
<i>NoPhon</i>	-	-	2.3	0.5	0.0	0.0	2.3	0.5
<i>UnIntPhon</i>	17.8	17.6	7.3	13.8	0.9	2.4	25.8	33.8
<i>IntPhon</i>	1.6	1.7	0.8	1.3	0.1	0.5	2.4	3.5
<i>VarUnIntPhon</i>	<b>11.7</b>	<b>6.5</b>	1.8	2.4	0.3	1.0	<b>13.8</b>	<b>9.3</b>
<i>VarIntPhon</i>	4.7	1.8	0.8	0.5	0.1	0.4	5.6	2.6
<i>Total</i>	35.8	27.7	12.9	18.5	1.3	3.6	50.0	50.0

In table 5 it can be seen that the hearing children produced significantly more utterances with one and two articulatory movements than the deaf children.

The following combination of articulation and phonation types are produced significantly *more by deaf* than by hearing children:

- variegated uninterrupted phonation without articulatory movement
- variegated interrupted phonation without articulatory movement
- one articulatory movement without phonation

Utterances with the following combination of articulation and phonation types are produced significantly *more by hearing* than by deaf children:

- one articulatory movement combined with uninterrupted phonation
- two or more articulatory movements combined with uninterrupted phonation
- two or more articulatory movements combined with interrupted phonation
- two or more articulatory movements combined with variegated uninterrupted phonation

To get more information about the development of the production of these utterance types, we calculated running averages over 3-months periods for the seven types of articulation and phonation which differed significantly between the deaf and hearing children. Figures 4 to 6 show these results for respectively utterances without articulation, with one articulation and with two or more articulations. Here it can be seen that the development of these utterance types is different for deaf and hearing children in the period studied. Detailed information about these results is presented in tables 6 to 8.

## Utterances without articulation

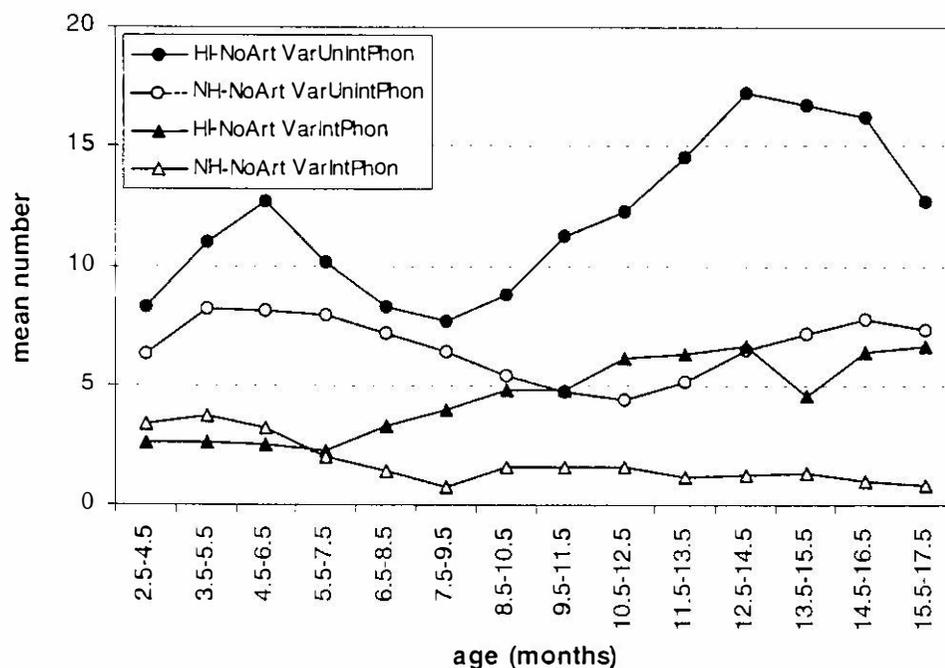


Figure 4. Running averages of the utterances with variegated (un)interrupted phonation without articulation produced by the deaf and hearing children.  $n = 8-18$  for the HI group and  $n = 15-18$  for the NH group (see table 5 for more details).

Table 6. Presentation of the mean number of utterances with variegated (un)interrupted phonation without articulation of deaf and hearing children. The table gives running averages over 3-months periods and standard deviations (sd.). Also for every period the number of deaf and hearing children is given ( $n$ ) and the signficancy according to a Mann-Whitney U Test ( $p < .05$ ).

age (months)	n		NoArt VarUnintPhon						NoArt VarIntPhon				
	HI	NH	HI		NH		sign	HI		NH		sign.	
			average	sd	average	sd		average	sd.	average	sd.		
2.5-4.5	8	18	8.3	6.1	6.3	5.9	ns	2.6	2.2	3.4	4.1	ns	
3.5-5.5	12	18	11.0	10.1	8.2	6.5	ns	2.6	2.0	3.7	3.9	ns	
4.5-6.5	15	18	12.7	11.8	8.1	6.3	ns	2.5	2.2	3.2	2.7	ns	
5.5-7.5	18	18	10.6	11.4	7.9	5.0	ns	2.3	2.1	2.0	2.5	ns	
6.5-8.5	18	18	8.3	9.1	7.2	4.3	ns	3.3	4.0	1.4	2.2	ns	
7.5-9.5	18	18	7.7	8.5	6.4	4.2	ns	4.0	4.5	0.8	1.1	<.027	
8.5-10.5	18	18	8.8	8.9	5.4	4.1	ns	4.8	5.2	1.6	2.5	ns	
9.5-11.5	18	18	11.2	9.6	4.5	3.1	<.031	4.8	4.4	1.6	2.5	<.05	
10.5-12.5	17	17	12.2	8.3	4.4	2.5	<.005	6.2	4.9	1.6	2.4	<.002	
11.5-13.5	16	16	14.5	8.5	5.1	3.4	<.002	6.3	5.7	1.2	1.0	<.001	
12.5-14.5	15	15	17.2	9.1	6.5	3.9	<.001	6.7	5.6	1.3	1.7	<.001	
13.5-15.5	15	15	16.7	8.0	7.2	3.9	<.001	4.5	4.7	1.3	1.7	<.007	
14.5-16.5	15	15	16.2	8.1	7.8	3.8	<.002	6.4	7.6	1.0	1.7	<.001	
15.5-17.5	15	15	12.7	7.6	7.3	3.9	<.044	6.7	8.1	0.9	0.8	<.001	
mean	80	88	11.7	9.4	6.5	4.6	<.001	4.7	5.3	1.8	2.6	<.001	

## Utterances with one articulation

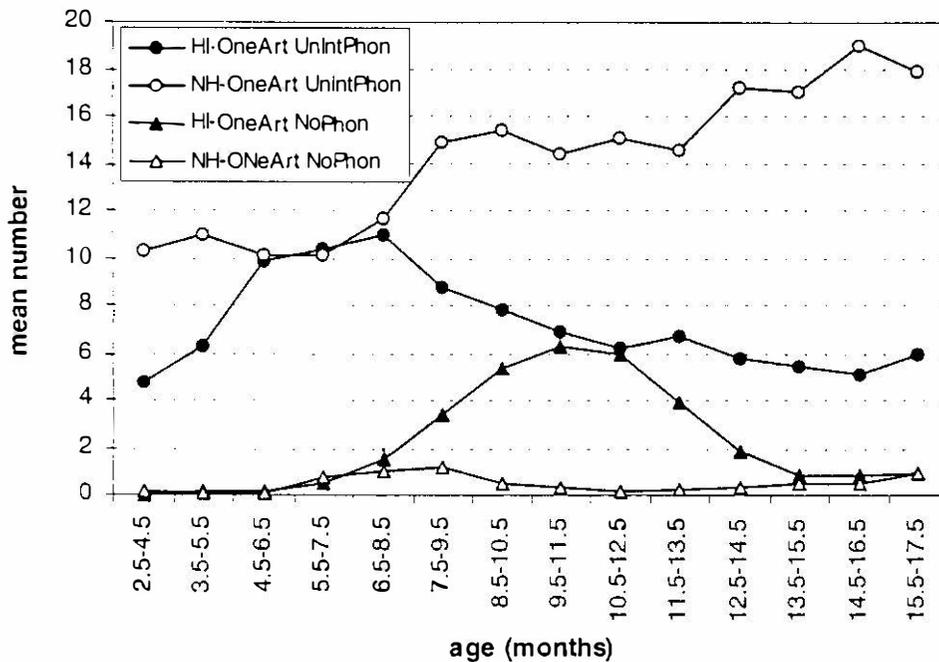


Figure 5. Running averages of the utterances with one articulation produced by the deaf and hearing children.  $n = 8-18$  for the HI group and  $n = 15-18$  for the NH group (see table 6 for more details).

Table 7. Presentation of the mean number of utterances with one articulation combined with uninterrupted phonation of deaf and hearing children. The table gives running averages over 3-months periods and standard deviations (sd.). Also for every period the number of deaf and hearing children is given (n) and the significance according to a Mann-Whitney U Test ( $p < .05$ ).

age (months)	n		OneArt NoPhon					OneArt UnIntPhon				
	HI	NH	HI		NH		sign	HI		NH		sign.
			average	sd	average	sd		average	sd.	average	sd.	
2.5-4.5	8	18	0.0	0.0	0.2	0.4	ns	4.8	2.7	10.3	11.2	ns
3.5-5.5	12	18	0.2	0.4	0.1	0.3	ns	6.3	4.1	11.0	10.8	ns
4.5-6.5	15	18	0.2	0.4	0.1	0.2	ns	9.9	10.0	10.1	10.0	ns
5.5-7.5	18	18	0.5	1.0	0.8	2.0	ns	10.4	9.8	10.1	6.6	ns
6.5-8.5	18	18	1.5	3.2	1.0	2.1	ns	11.0	9.7	11.6	6.7	ns
7.5-9.5	18	18	3.4	6.6	1.2	2.1	ns	8.8	7.9	14.9	6.5	<.013
8.5-10.5	18	18	5.4	8.5	0.5	1.0	ns	7.8	7.8	15.4	6.4	<.007
9.5-11.5	18	18	6.3	9.1	0.3	0.5	<.02	6.9	8.1	14.4	7.7	<.009
10.5-12.5	17	17	5.9	8.9	0.2	0.4	<.003	6.2	6.8	15.1	7.6	<.003
11.5-13.5	16	16	3.9	7.4	0.3	0.8	<.010	6.7	7.5	14.6	7.9	<.008
12.5-14.5	15	15	1.9	5.6	0.3	0.8	ns	5.8	6.8	17.2	7.4	<.001
13.5-15.5	15	15	0.9	1.4	0.5	1.1	ns	5.5	6.0	17.0	7.1	<.001
14.5-16.5	15	15	0.9	1.3	0.5	1.1	ns	5.1	6.5	19.0	5.8	<.001
15.5-17.5	15	15	0.9	1.3	0.9	1.3	ns	6.0	7.1	17.9	4.8	<.001
mean	80	88	2.3	5.6	0.5	1.2	<.04	7.3	7.7	13.8	8.3	<.001

## Utterances with two or more articulations

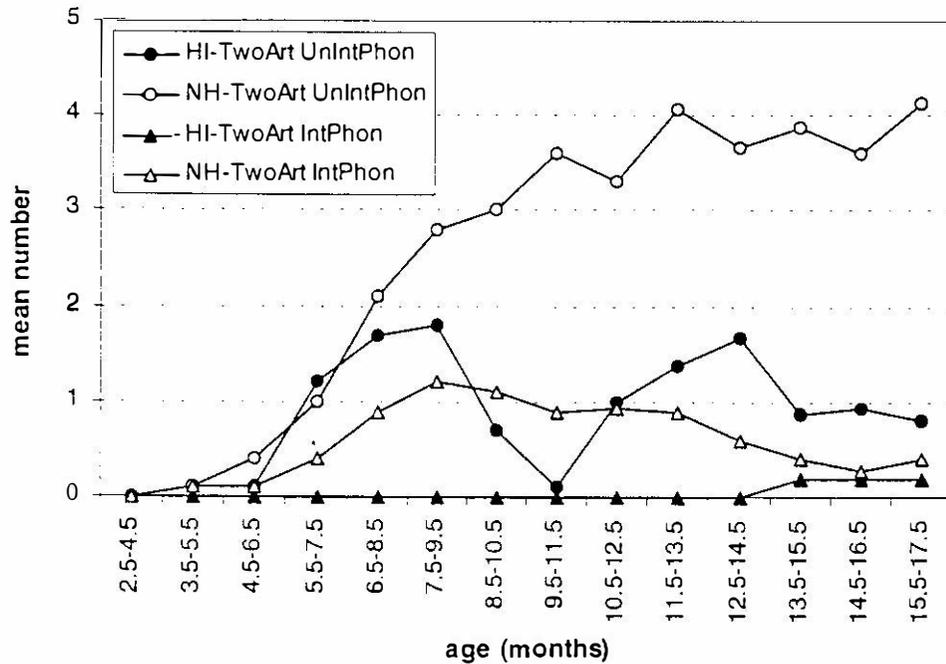


Figure 6. Running averages of the utterances with two or more articulations combined with (un)interrupted phonation produced by the deaf and hearing children.  $n = 8-18$  for the HI group and  $n = 15-18$  for the NH group (see table 7 for more details).

Table 8. Presentation of the mean number of utterances with two or more articulations combined with (un)interrupted phonation of deaf and hearing children. The table gives running averages over 3-months periods and standard deviations (sd.). Also for every period the number of children is given ( $n$ ) and the significance according to a Mann-Whitney U Test ( $p < .05$ ).

age (months)	n		TwoArt UnIntPhon					TwoArt IntPhon				
	HI	NH	HI		NH		sign	HI		NH		sign.
			average	sd	average	sd		average	sd.	average	sd.	
2.5-4.5	8	18	0.0	0.0	0.0	0.0	ns	0.0	0.0	0.0	0.0	ns
3.5-5.5	12	18	0.1	0.3	0.1	0.3	ns	0.0	0.0	0.1	0.2	ns
4.5-6.5	15	18	0.1	0.3	0.4	0.9	ns	0.0	0.0	0.1	0.2	ns
5.5-7.5	18	18	1.2	4.7	1.0	1.5	<.035	0.0	0.0	0.4	1.7	ns
6.5-8.5	18	18	1.7	5.1	2.1	2.7	<.017	0.0	0.0	0.9	1.8	<.018
7.5-9.5	18	18	1.7	5.1	2.8	3.1	<.005	0.0	0.0	1.2	1.9	<.001
8.5-10.5	18	18	0.7	2.4	3.0	3.2	<.001	0.0	0.0	1.1	1.3	<.001
9.5-11.5	18	18	0.1	0.2	3.4	2.9	<.001	0.0	0.0	0.9	1.1	<.001
10.5-12.5	17	17	1.0	3.9	3.3	2.7	<.001	0.0	0.0	0.9	1.2	<.001
11.5-13.5	16	16	1.4	4.0	4.1	2.6	<.001	0.0	0.3	0.9	1.0	<.005
12.5-14.5	15	15	1.7	4.1	3.7	2.6	<.004	0.0	0.3	0.6	1.1	ns
13.5-15.5	15	15	0.9	1.3	3.9	2.4	<.001	0.2	0.6	0.4	0.7	ns
14.5-16.5	15	15	0.9	2.0	3.6	2.5	<.002	0.2	0.6	0.3	0.6	ns
15.5-17.5	15	15	0.8	2.0	4.1	3.2	<.001	0.2	0.6	0.4	0.7	ns
mean	80	88	0.9	3.2	2.4	2.9	<.001	0.1	0.3	0.5	1.1	<.001

Figure 4 shows the results for utterances without articulation combined with variegated (un)interrupted phonation. From the age period 9.5-11.5 months onwards the differences between the two groups of children were significant (Mann-Whitney U Test,  $p < .05$ , see table 6). From that age onwards the deaf children produced more utterances with variegated phonation without articulation. For a short period deaf children also produced more utterances with one articulation without phonation. Around the same time, as can be seen in figures 5 and 6, the hearing children start to produce more utterances with one or two articulations combined with 'normal' (un)interrupted phonation. They also produced more utterances with two or more utterances combined with variegated uninterrupted phonation. This type of utterance is not plotted in figure 6 because there was only an overall significant difference, which could not be represented in a certain ageperiod. During the period studied the hearing and deaf children followed the same pattern in their production of this utterance type. Utterances with two or more articulations often are babbles. In the period studied here one deaf child started babbling. This child started to produce babbles at the same time as hearing children did, namely at about 8.5 months old. The data in figure 6 and table 8 for the deaf children are almost completely produced by this child only.

#### 4 Discussion and conclusion

In this study it was observed that during the first eighteen months of life several differences can be found in the speech sound production of deaf and hearing children. Differences were found in the number of spoken utterances, in utterance duration, and in the types of articulation and phonation. However, these results give no information yet about the quality of the utterances of the children. This will be subject of future analyses.

Apart from the number of utterances, most differences between deaf and hearing children started to become significant at about 8.5-10.5 months of age. About this time deaf children start to vary more in their phonation and also produce utterances with a longer duration. At the same time the *number* of their utterances decreases. A possible explanation for this decrease is that the utterances the children produce from this age are more difficult (more variation in phonation and longer duration). About this age of 8.5-10.5 months the hearing children start to produce more utterances with articulations. The utterance duration of the hearing children slightly increases from the age period of 6.5-8.5 months, possibly due to the fact that they also start producing babbles at this time which have a longer duration. After the age period of 7.5-9.5 months the duration decreases while the number of utterances with articulations is still increasing. From this age onwards they produce more difficult types of utterances and later on they start with spoken word production. Possibly therefore they have a shorter utterance duration in this period.

In general it seems that at the age where hearing children start to produce utterances with more articulations (i.e. canonical babbling), deaf children start to make more variation in their phonation. At the same time (for a short period) the deaf children start to produce utterances with one articulation without phonation. Possibly the variation in phonation is a sort of compensatory behavior. Because producing a combination of articulation and phonation is too difficult for them, they just use only

phonation or only articulation. This process starts at about the second half of the first year of life. Before that age there is much more similarity between the two groups of children. Possibly the lack of auditory feedback starts to play a clear role in the production of utterances after the first half year of life. Before this age the production of utterances is more anatomically and physiologically based. But feedback possibly plays a role in the interaction, resulting in the production of more spoken utterances by the deaf children.

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