SPEECH PATTERN ACQUISITION IN PROFOUNDLY HEARING IMPAIRED CHILDREN

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It is well known that even profoundly hearing-impaired children can, in particular instances, acquire highly intelligible speech and excellent conversational skills if educated in an appropriate speaking-hearing environment. The detailed course of their speech development has not, however, been studied. In this paper we outline some of our first findings from a long-term study of the perceptual and productive phonological development of an unselected group of 17 severely-profoundly hearing-impaired children, a whole class, who were aged between 7 and 8 at the start of the project in October 1984. All the children were pre-lingually hearing-impaired and had been fitted with hearing-aids at an early age. Their pure tone audiogram average in the better ear at .5, 1 and 2 KHz varied between 83 and 115 dB. A principal result of the work indicates the extent to which, during the first two years, the children follow an essentially normal pattern of development albeit with a delay which, for some speech contrasts may be great.

Normal phonological development

Observation of the phonology of normally hearing children over the first few years of life shows the development of the ability to control the larynx and vocal tract to produce low frequency, high intensity simple acoustic speech patterns before rapidly changing, high frequency complex elements and patterns. Thus we see the development of control of adequate phonation and fundamental frequency changes in the first year of life, enabling the intonational foundations of conversation to be laid. The contrastive vowel system of the child's language is acquired during the second and third years, but a fully contrastive system of consonants is often not present until 5 - 7 years of age. Phonetic accuracy and stability take several more years. From both acoustic/auditory and articulatory points of view there is a progression from simple to complex, and, within the consonant system a stable voiced-voiceless contrast is slow to mature, and sibilant fricatives and velar consonants are acquired relatively late. [1, 2] Two phonological contrasts from the long-term study have been chosen for discussion here. The first is a vowel contrast, that between [ɜ] and [ɑ], phonemically adjacent but acoustically distinct; and the second is the voicing contrast, salient in itself, between the complex velar plosives [k] and [g]. Children would be expected to acquire the vowel contrast before the voicing contrast, and not to produce the contrasts consistently unless they were perceived contrastively.

Speech Perception Tests: Procedure

The two chosen minimal pairs - [ɜ]-[ɑ] and "goat-coat" - were synthesised on a hardware parallel synthesiser to closely match natural tokens spoken by a female speaker known to the subjects. 6-token continua were then built, in which the most salient parameters marking the contrast, F1 and F2 in the vowel contrast, Voice Onset Time and F1 onset in the voicing contrast, were altered in equal steps, all other speech patterns remaining constant.

The vocalic minimal pair consisted of two-formant syntheses, with F1 varying from 500 Hz in the extreme [ɜ] to 900Hz in the extreme [ɑ] and F2 varying between 1666 Hz in [ɜ] and 1400 Hz in [ɑ]. Stimuli were synthesised with a falling intonation (initial and final values: 237 Hz-155 Hz). A "goat-coat" minimal pair was used to investigate the voicing contrast. The two patterns under investigation were: Voice Onset Time, varying from 20 ms in "goat" to 100 ms in "coat", and the onset frequency of the first formant (F1). A more detailed description of the stimuli can be found in Hazan and Fourcin [3].

The stimuli were presented using a forced-choice identification test procedure. A computer-controlled adaptive testing procedure was used so that the length of the test and degree of complexity were dependent on the subject's ability. The outcome of the test was an identification or "labelling" curve in which the percentage of responses of one label were plotted across the stimulus range. Labelling curve configuration enables one to assess not only the ability to identify the extremes of the range, which are well differentiated, but also to consistently group similar stimuli into a same category. It therefore provides a controlled measure of the way in which subjects deal with the inherent variability of speech.

Simon and Fourcin [4] described three main types of labelling curve configuration which are found as a subject's labelling ability progresses. At first, random labelling may be obtained, where random responses occur even to the extremes of the stimulus range. As development proceeds, progressive labelling is seen. Here, extremes are labelled appropriately but inconsistent labelling is given to intermediate stimuli. Finally categorical labelling is obtained, where the intermediate stimuli are consistently labelled into two clear categories.

On average, three assessments per year were obtained, and labelling tests were presented to the subjects at each testing session. Stimuli were presented free-field, from a loudspeaker situated in front of the subject at a distance of about a metre. The subjects were wearing their own hearing aids. This method of presentation was chosen to best match the children's listening experience.

A detailed examination of labelling function configuration over time offers great insights into the children's stage and rate of development, as has been seen in previous studies [4, 3]. In this overview, however, rather than examining the detailed development in labelling ability in the 17 subjects over a two year period, the general trend in development seen in their ability to label both the vowel and voicing contrast will be compared to the progress seen in their ability to appropriately produce these contrasts. The types of labelling curve configuration found at the beginning andend of the testing period for both contrasts are given in Table I. Subjects are ranked in terms of increasing pure tone threshold average (better ear average over .5,1,2 KHz).

Perception Tests - Results

General development is seen in most children over the two year period, most clearly visible in the children's increasing ability to label the vowel contrast. At the beginning of the testing period, 8 children out of the 17 tested were labelling the vowel contrast at random. Two years later, only one of the children was still giving random labelling to these stimuli. The rate of progress from random to categorical labelling was found to vary from child to child.

In terms of the order of development of contrasts, as in a previous study [3], it appears that the children were categorically labelling the vowel contrast before the more acoustically complex voicing contrast. Because of their short attention span, many of the subjects intially having most difficulty in the labelling of the vowel contrast were not tested on the voicing contrast, after initial live training tests had shown their inability to respond to the extremes of the range. Out of the 8 subjects who were tested on both contrasts at the beginning of the testing period, 2/8 give random labelling to the vowel contrast, while 6/8 gave random labelling to the voicing contrast. In March 1987, all children in this group could label the vowel contrast amd 1/8 was labelling the voicing contrast, at random 7/9 of the more impaired subjects not tested earlier were labelling the voicing contrast at random in March 1987.

Speech production assessment

Recordings have been made three times a year using both conventional microphone and laryngograph techniques. The laryngograph allows non-invasive monitoring of vocal fold activity during normal speech production, and information is thus available for subsequent computer analysis of a range of vocal fold parameters including fundamental frequency [5]. Each speech sample includes some spontaneous conversation, citation forms illustrating certain phonological contrasts, and a traditional picture naming articulation test. The [ɜ] - [ɑ] and [g] - [k] contrasts are elicited in citation form by showing pictures of 2 animals whose names are the vowels concerned (as in the perception tests) and pictures of a coat and a goat which the child labels. At the first recording session the vowels were elicited by imitation.

Discussion of Production

Mere tabulation of binary results inevitably simplifies a complex picture, and, to some extent, can obscure detailed findings which are relevant to a more comprehensive view of phonological development. One important factor is variation in the pronunciation of the test items and of other words in the children's vocabularies that contain the same segments. At the start of the study, in vowel production, the children with less hearing cannot produce the contrast by imitation or labelling but do have a few well known words that are phonetic approximations to adult forms, with [ɜ] and [ɑ] appropriately used, in their spontaneous speech, or produced in the picture naming traditional articulation test. These children are at an even earlier stage of consonant development, and [k] and [g] never appear. The children with better hearing, however, on the whole, have no trouble with the vowels in labelling or spontaneous speech, but show a similar picture for the velar consonants as the more impaired group show for the vowel contrast: inability to produce citation minimal pairs but some appropriate use of velars in a few lexical items. This behaviour could be considered pre-phonological as contrastiveness cannot be demonstrated; but the foundation for it is present as the sounds can be articulated and in some cases matched to the equivalent segments in adult pronunciations. Children at this stage of development may or may not show categorical labelling of the contrasts concerned.

In the speech development of normally hearing children this pre-phonological stage occurs at about eighteen months of age when the child has only a very small vocabulary of some 50 words. For the 7 and 8 year old hearing impaired children, at the start of this study the stage had, therefore, developed several years later - for the contrasts under investigation: not all aspects of phonology were delayed at this stage except for the most severely impaired speakers. The less handicapped children showed well-developed syntax and intelligible speech although with some immaturities such as fronting and stopping of fricatives [1].

In general, two years later a similar picture of vowel development preceding voicing is seen: the less hearing-impaired children who still do not have a [k] - [g] contrast nevertheless now use the

velar consonants in some words, and the same is true for the more impaired speakers' vowels. Although progress is thus very slow and delayed, it is, however, following the normal pattern.

Discussion and Conclusion

Evidence of age-related development in the ability to label increasingly complex contrasts is found in these profoundly hearing-impaired children almost without exception. This development seems to be following a normal course, in terms of the order in which the contrasts are acquired and the manner in which they are individually established. Although this development is delayed by at least four to five years compared to normally-hearing children, it is part of an ongoing progression.

Some variability is found in the stage of development reached by these subjects from a homogeneous age-group. This variability is not fully explained by their degree of residual hearing, although there appears to be a gross difference between more and less advanced children, with a division around an average better ear pure tone loss of 100 dB SL. The results of our work are surprising and encouraging in regard to the auditory speech skill development shown possible in a group of unselected profoundly hearing-impaired children. It is likely, however, that with the use of hearing aids designed explicitly to enable the maximum use of their residual hearing, even greater and earlier speech receptive development could occur.

Table 1 : *Results of Perception Tests*

Child	P,T.A.	Ranking PTA - Nov 1986 Vowel March 85	Voicing July 85	Vowel March 87	Voicing March 87
1	83	P	R	C	C
2	90	R	R	C	R
3	93	R	R	C	C
4	93	P	R	P	P
5	95	P	P	C	C
6	97	P	R	C	P
7	102	P	P	C	C
8	102	R	-	P	R
9	108	R	-	C	R
10	108	P	R	P	P
11	108	R	-	R	R
12	108	P	-	C	R
13	110	P	-	C	P
14	110	R	-	P	R
15	110	R	-	C	R
16	112	P	-	P	P
17	115	R	-	P	R

P = Progressive labelling = at least 87% correct at extremes
C = Categorical = at least 4 steps labelled with 100% consistency
R = Random

Table 2 : *Production of vowel and voicing contrasts in citation forms*

Child	P.T.A.	March 85 Vowels	March 85 Voicing	March 87 Vowels	March 87 Voicing
1	83	Y	Y*	Y	Y
2	90	N	N	Y	Y
3	93	N	N	Y*	N
4	93	Y	Y	Y	Y
5	95	Y	Y	Y	Y
6	97	Y	Y*	Y	N
7	102	N	Y*	Y	Y
8	102	N	N	Y	N
9	108	N	N	Y*	N
10	108	Y	N	Y*	N
11	108	N	N	N	N
12	108	Y*	N	Y*	N
13	110	Y	N	Y	N
14	110	N	N	N	N
15	110	N	N	N	N
16	112	N	N	Y*	N
17	115	N	N	Y*	N

Key: Y = Yes: child consistently produces the contrast
N = No: child produces only one segment or different sounds randomly
* = Clear contrast, consistently produced, but immature phonetically: velars are palatalised; [ɑ] centralised sometimes

Notes: Each contrast was produced at least twice.
Child 11 was recorded for the first time in July 85, and the most recent results for Child 3 are from October 86.

References

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