The Effectiveness of the Intonation Meter for Teaching Intonation to Deaf Persons

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Abstract. Prelingually, profoundly deaf speakers frequently experience problems in generating a proper intonation. For this reason several attempts have been made to improve their intonation with the help of visual intonation-display systems. A system has been developed, called the Intonation Meter, in which visual feedback of intonation is given as a continuous representation of the pitch contour containing only the perceptually relevant aspects of the intonation pattern. Two exploratory studies were carried out to determine the effectiveness of the Intonation Meter for teaching intonation to prelingually profoundly deaf children aged 6 to 18 years. The results indicate that the Intonation Meter can be an effective tool for teaching intonation to older children, i.e. children of nine years and older. Furthermore, younger children (i.e. 6-7-year-olds) receiving intonation training progressed well, irrespective of whether or not the Intonation Meter was used.

1 Introduction

Many investigators have reported on the problems that prelingually, profoundly deaf children have with pitch control [1-3]. The characteristic difficulties include abnormally high pitch [1, 3] and a lack of linguistically relevant pitch variations resulting in unnatural intonation patterns [2]. A better production of pitch contours is important because it contributes to speech quality [3] and speech intelligibility [4].

It is difficult for deaf speakers to learn to control the pitch of speech for three main reasons. First, deaf speakers may not have sufficient residual hearing capacities to perceive the auditory cues necessary for the control of pitch. Secondly, other feedback modalities, such as tactile and proprioceptive feedback, play no or only a minor role in pitch control [5]. Finally, the major variations in pitch are determined by the action of the cricothyroid muscle [6], which means that it is impossible to give visible cues on the underlying physical mechanism of intonation. Thus, a process-oriented approach in which the attention of the pupil is focussed on the processes responsible for the production of pitch cannot be applied for teaching intonation. Therefore, to help profoundly deaf speakers acquire better pitch control, various researchers have developed sensory aids that extract the pitch from speech and display it visually [7, 8]. They allow for a product-oriented approach for teaching intonation to deaf speakers in that they can circumvent the disrupted auditory feedback loop by providing information on pitch via the visual channel.

Although visual intonation-display systems may be useful in teaching intonation to deaf speakers, they are not widely used in schools. One factor that may have contributed to this is that little is known about the effectiveness of these systems in teaching intonation to prelingually, profoundly deaf persons. Another important factor that may have contributed to the absence of widespread use of visual display systems

in schools is that, in these systems, pitch was measured and fed directly back to the deaf speaker without post-processing the pitch contour. Two problems arise when speakers have to interpret an unprocessed pitch contour. The first problem arises from the fact that the interpretation of the displayed pitch contour is hampered by the interruptions during unvoiced parts which are at variance with the continuously perceived course of pitch. The second problem relates to the presence of many perceptually irrelevant pitch variations, also called micro-intonation, which may distract attention from the perceptually relevant pitch variations. In order to solve these problems, a system has been developed, called the Intonation Meter, that gives visual feedback on intonation as a continuous representation containing only the perceptually relevant pitch variations. This results in the so-called stylized pitch contours [9]. This means that unvoiced parts are interpolated and the course of the pitch contour is approximated by a small number of straight lines without the perceptually relevant properties being affected. This representation of the pitch contour is intended to facilitate the interpretation of the visual feedback of the intonation contour [9].

The apllicability of the algorithms for measuring pitch and stylizing the pitch contours was evaluated for speech utterances of deaf speakers and their speech therapists in a study reported by Spaai [10]. It was found that the algorithms for measuring pitch and stylizing pitch contours performed satisfactorily and needed no further adaptation for application in speech training situations of deaf speakers.

In the following sections two explorative studies will be presented that were carried out to determine the effectiveness of the Intonation Meter for teaching intonation to prelingually profoundly deaf children. In the final section the results will be discussed and suggestions will be given for increasing the effectiveness of the system for teaching intonation to prelingually, profoundly deaf children.

2 Study 1: The Effectiveness of the Intonation Meter for Teaching Intonation to Deaf Children Aged 14 to 20 Years

2.1 Design and Procedure

Two groups of profoundly deaf students practised intonation. The first group, the *control group*, practised intonation with the help of regular means. This group received speech training using mainly auditory input via personal hearing aids. The second group, the *experimental group,* received speech training using auditory input and the Intonation Meter to provide visual feedback on pitch. Typically, when a student was working with the system, an example of a pitch contour was produced by the speech therapist and displayed on the upper part of the screen of the Intonation Meter and then had to be imitated on the lower part. While imitating, direct unprocessed feedback was given by means of real-time pitch measurements. After the conclusion of the whole utterance, the stylized contour was also calculated and displayed. Progress in learning of both groups was compared with that of a third group, the *reference group,* which did not receive any extra practice in intonation.

Progress in learning was measured as differences in intonation tests that were conducted prior to training and at the end of the training period. These tests were based on the Fundamental Speech Skills Test [11]. The intonation test was conducted without sensory aids except for the students' personal hearing aids. The students' productions were tape-recorded and a speech therapist who was experienced in listening to and evaluating the speech of deaf children rated the recordings. For this explorative

study results are reported for: 1) the production of appropriate average pitch in words and sentences; 2) the production of pitch variations in long vowels and syllables.

2.2 Training Sessions

The experimental group and the control group practised intonation three times a week, each session lasting about 15 minutes. This was done over a four-month period. Generally speaking, speech training focussed on the remediation of an inappropriate average pitch and, to a lesser extent, on the production of variations of pitch in vowels and syllables. Practice consisted of four groups of activities: pitch-awareness training, auditory discrimination and identification of pitch contours, imitation of pitch contours and production of pitch contours without the benefit of the teacher's model.

2.3 Subjects

Twelve prelingually, profoundly deaf students from a secondary school for special education at the Institute for the Deaf in Sint-Michielsgestel, the Netherlands, participated in the experiment. They had been educated according to the 'oral reflective method'. The age of the subjects ranged from 14 to 20 years. All the students had hearing losses greater than 90 dB ISO bilaterally. They produced pitch contours that were perceived by their speech therapists as 'relatively flat', reflecting a monotonous voice. Also, in some cases, their pitch appeared to be too high for their age and sex. The subjects were matched in groups of three as closely as possible in terms of their age, residual hearing, school performance and speech skills. After the subjects had been divided into three groups, one subject dropped out. The numbers of children participating in the control condition, the experimental condition and the reference condition were three, four and four, respectively.

2.4 Apparatus

Use was made of the Intonation Meter, which is capable of providing unprocessed and stylized visual feedback on intonation. The core of the Intonation Meter consists of an AT386 computer running under DOS with a 80387 co-processor extended with a TMS320C25-based Digital Signal Processor board (DSP), a 80 Mb hard disk, a VGA colour monitor and an audio interface. This audio interface is connected to two input microphones, one for the speech therapist and one for the deaf child. Speech input is amplified and low-pass filtered by the audio interface with a cut-off frequency of 2500 Hz. The output of the audio interface is then fed into the input of the DSP board, which is capable of analysing the speech signal. Analysis implies the computation of pitch and amplitude via the method of subharmonic summation. The unprocessed pitch measurements are displayed in real-time. Immediately after the speech utterance, the stylization based on the raw pitch measurements can be calculated and displayed [9].

2.5 Results

Average Pitch. Fig. 1 shows the percentages of acceptable ratings in the pretest and the posttest for the average pitch in isolated words (22 items) and sentences (12 items). The data are presented for the experimental group, the control group and the reference group. It is immediately apparent that the experimental group made more progress than the reference group and the control group. Furthermore, the control group performed better than the reference group.

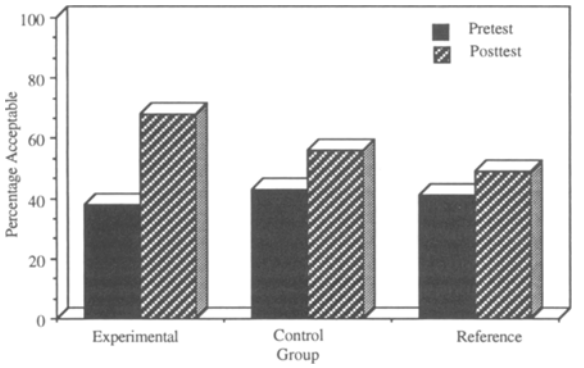

Fig. 1. Average ratings of the mean pitch. The percentages of acceptable judgments are plotted for the experimental group, the control group and the reference group. The appropriateness of average pitch in isolated words (22) and sentences (12) has been rated. The data are presented for the pretest (dark bars) and the posttest (light bars).

Pitch Variations in Vowels and Syllables. Fig. 2 shows the percentages of acceptable ratings in the pretest and the posttest for the production of variations in pitch in long vowels (135 items) and syllables (18 items). The data are presented for the experimental group, the control group and the reference group. The results clearly show that the experimental group made most progress (64%). The control group and the reference group also showed progress but the magnitude of improvement was not as large: the percentage of acceptable judgments increased by about 17%.

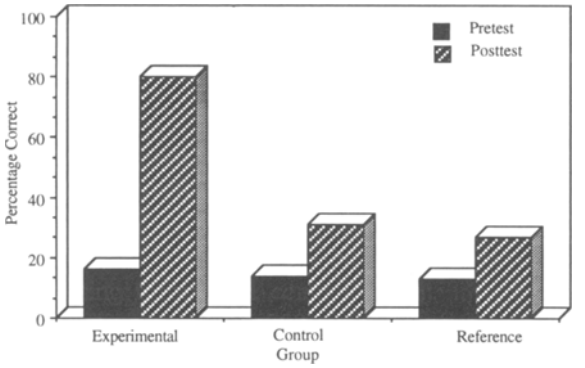

Fig. 2. Average ratings of the production of pitch variations in vowels (135) and syllables (18). The percentages of acceptable judgments are plotted for the experimental group, the control group and the reference group. The data are presented for the pretest (dark bars) and the posttest (light bars).

2.6 Discussion

The results of this study showed that children who received intonation training by means of both regular methods and the Intonation Meter showed more progress in the production of appropriate average pitch and the production of pitch variations in vowels and syllables than a matched control group that practised intonation merely by

means of regular methods and a reference group that did not receive any extra intonation training. Moreover, the differences in progress between the control group and the reference group were limited, illustrating that teaching intonation to a profoundly deaf person by means of regular methods is an extremely difficult task. The children who participated in this study could probably be characterized as having more impervious phonatory problems owing to their age. Furthermore, it is hypothesized that intonation training is more effective when it is initiated after an intonation problem arises. This may prevent the development of incorrect speech habits which are difficult to remediate. Generally speaking, this implies that intonation training should be commenced at a very young age [1]. This hypothesis is in agreement with the results of studies on second-language learning that showed that teaching the intonation of a foreign language is more effective with younger children than with older children. However, it is unknown whether a visual intonation-display system can be used for teaching intonation to young deaf children. Young children may be unable to relate the visual representation of the pitch contour to the corresponding speech signal or to integrate the visual representation of speech with the orosensoric and the residual auditory representation of speech.

3. Study II: The Effectiveness of the Intonation Meter for Teaching Intonation to Deaf Children Aged 6 to 11 Years

3.1 Design and Procedure

A single-subject A-B-A-B withdrawal design was used to assess the intervention effects, i.e. the effects of intonation training by means of regular methods (A-phase) and the effects of intonation training by means of regular methods involving the use of the Intonation Meter (B-phase). This design typically involves a baseline phase followed by a treatment phase. Then the treatment is withdrawn, and this is followed by a return to the treatment phase.

Each phase included 9 experimental sessions: successively, a test session, three training sessions, an intermediate test session, three training sessions and a final test session. Experimental sessions were conducted three times a week with the experimental group. This was done over a four-month period. Each training session took about 10 minutes. For each phase a specific set of intonation patterns was trained and tested using speech materials varying from vowels to syllables and simple words consisting of two or three syllables.

A test session lasted about 5 minutes. Children were instructed to imitate a certain intonation pattern on a specific vowel, syllable or word that was produced by the speech therapist. The students' productions were tape recorded and were rated by a listener of normal hearing experienced in listening to and evaluating the speech of deaf children. A dichotomous scoring system (acceptable/unacceptable) was used to grade each response.

Initially, in the *Introduction Phase*, the deaf child received some pitch-awareness training. Furthermore, some time was allotted to auditory discrimination and auditory identification of pitch contours where training focussed on the acoustical signal using the student's hearing aids while eliminating cues from speechreading and other modalities. Following this, children were assigned to a Baseline Phase or a Treatment Phase. Both phases are described below.

Baseline Phase (Phase A). In the Baseline Phase intonation was only trained by

means of regular methods. For instance, a pitch contour was produced on a vowel or syllable and the child was instructed to imitate this. Information on pitch was also presented via some visual activity of the speech therapist, e.g. raising or lowering the hand to indicate the pitch level. No visual or tactile sensory aid was used in the Baseline Phase. Besides imitation of pitch contours produced by the speech therapist, intonation training involved the production of pitch contours without the benefit of the teacher's model.

Treatment Phase (Phase B). In the treatment phase, intonation was trained by means of both regular methods (see the Baseline Phase) and the Intonation Meter to provide visual feedback on intonation.

3.2 Training Sessions

Generally speaking, speech training focussed on the production of intonation patterns in vowels and syllables. Furthermore, some time was devoted to the production of intonation patterns in words. On average, about 18 items (intonation patterns in approximately 6 vowels, 10 syllables and 2 words) were practised in each phase.

3.3 Subjects

Six prelingually, profoundly deaf pupils from the primary school for special education at the Institute for the Deaf in Sint-Michielsgestel, the Netherlands, participated in the experiment. All the children were being educated according to the 'oral reflective method' [21]. The age of the children ranged from 6 to 7 years and from 9 to 11 years, respectively. All the children had hearing losses greater than 90 dB ISO bilaterally. The mean pure-tone average was approximately 108 dB in the better ear, ranging from 92 dB to 130 dB ISO. All the children produced pitch contours that were perceived by their speech therapist as 'relatively flat', in that linguistically relevant pitch variations were absent.

3.4 Results

The results showed that the 9 to 11 year-olds progressed more under treatment conditions than under baseline conditions whereas the 6 to year-olds progressed well irrespective of whether or not the Intonation Meter was used.

Here, the results are presented for only two subjects since they are representative for their age groups. Figure 3 shows the experimental results for Subject 1, one of the children aged 9 to 11 years, and Figure 4 shows the results for Subject 2, one of the children aged 6 to 7 years. Both figures show the percentages of acceptable ratings for the production of pitch variations in vowels, syllables and words in the initial test, the intermediate test and the final test for the different phases.

Figure 3 shows the results for Subject 1. On the basis of visual inspection of the results it can be concluded that the performance gains, as determined by the differences between the scores of the initial tests and the scores of the final test, are greater under treatment conditions than under baseline conditions.

As for Subject 2, it is clear from Figure 4 that performance gains under baseline conditions were comparable to those under the treatment conditions. Furthermore, it was found that, irrespective of the phase in which the subject was practising the production of intonation patterns, the subject progressed well.

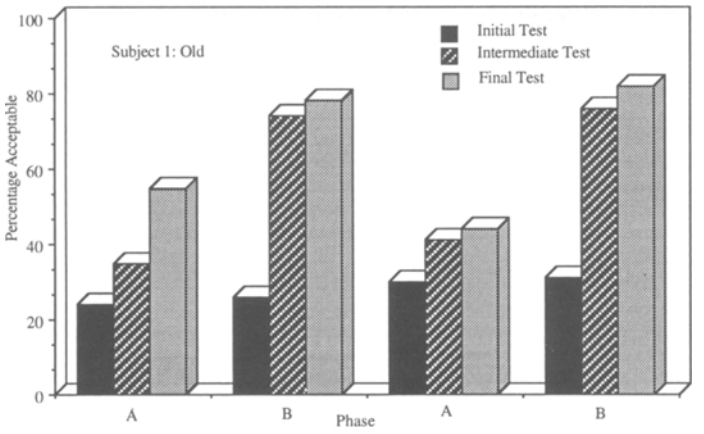

Fig. 3. Average ratings of the production of pitch variations in vowels, syllables and words. The percentages of acceptable judgments are plotted for baseline (A) and treatment (B) conditions for Old Subject 1. The data presented were obtained in the initial test, the intermediate test and the final test.

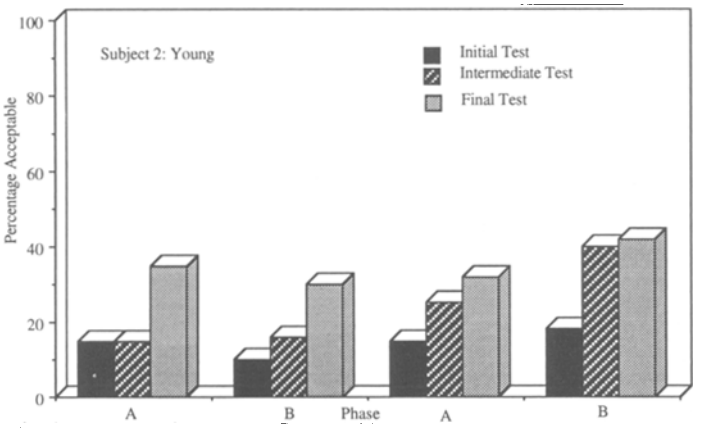

Fig. 4. Average ratings of the production of pitch variations in vowels, syllables and words. The percentages of acceptable judgments are plotted for baseline (A) and treatment (B) conditions for Young Subject 2. The data presented were obtained in the initial test, the intermediate test and the final test.

4. Discussion

The purpose of the research reported here was to determine whether the Intonation Meter can be effective for teaching intonation to profoundly deaf children. Contrary to what was expected, the older children made most progress when the Intonation Meter was used in addition to regular methods whereas the 6 to 7 year-olds progressed well irrespective of whether or not the Intonation Meter was used. A possible explanation for this differential effect is that for the young children learning to produce intonation patterns in vowels and syllables is a relatively easy task. For older children, however, this may be a more difficult task in which the use of the Intonation Meter may help to monitor appropriate pitch production which in turn may enhance the auditory, motoric and kinesthetic awareness of pitch variation, useful when learning to produce intonation patterns. This finding is in line with the results of the study by Tahta et al.

[12]. Tahta et al. [12] studied the abilities of 5 to 15 year-old monolingual English schoolchildren to replicate the intonation of a foreign language. Performance in the production of intonation patterns remained steadily good for the 5 to 8 year-olds and then dropped rapidly from 8 to 11 while the 11 to 15 year-olds showed comparably poor performance. This can possibly be explained by the fact that younger children have better *rote-memory ability* ,i.e. the ability to retain associations between stimuli and responses, than older children. Another possible explanation for the absence of a differential training effect in the case of the very young children is that they are not yet capable of relating the visual representation to the corresponding speech signal.

Foremost in clinical intervention is the need to generalize skills from more structured, imitative tasks to everyday situations. At present it is not known whether children with 'prosodic difficulties' easily transfer skills learned through intervention using elicited imitation to real-life communication situations. Long-term research is necessary to determine whether the intensive use of the Intonation Meter in regular speech training can result in improved control of intonation in connected discourse. This type of research is also necessary to verify the hypothesis that stylized pitch contours are more efficient in teaching intonation than unprocessed pitch contour representations.

5 References

1. C.M. Beijk, B.A.G. Elsendoorn: A comparison of fundamental frequency of deaf and hearing children aged 14 to 20 years. ESCA Workshop Speech and Language Technology for Disabled Persons. Stockholm, May -June 1993.
2. N.S. McGarr, M. Osberger: Pitch deviancy and the intelligibility of deaf children's speech. Journal of Communication Disorders 11, 237-247 (1978).
3. R.B. Monsen: Acoustic qualities of phonation in young hearing-impaired children. Journal of Speech and Hearing Research 22, 270-288 (1979).
4. D.E. Metz, N. Schiavetti, V.J. Samar, R.W. Sitler: Acoustic dimensions of hearing-impaired speakers' intelligibility: segmental and suprasegmental characteristics. Journal of Speech and Hearing Research 33, 467-478 (1990).
5. P. Ladefoged: Three areas of experimental phonetics. London, University Press, 1967.
6. R. Collier: Physiological correlates of intonation patterns. Journal of the Acoustical Society of America 58, 249-255 (1975).
7. K. Youdelman, M. MacEachron, A.M. Behrman: Visual and tactile sensory aids: Integration into an on-going speech training program. Volta Review 90, 197-207 (1988).
8. N.S. McGarr, J. Head, M. Friedman, A.M. Behrman, K. Youdelman: The use of visual and tactile sensory aids in speech production training: A preliminary report. Journal of Rehabilitation Research and Development 23, 101-109 (1986).
9. G.W.G. Spaai, A. Storm, D.J. Hermes: A visual display for the teaching of intonation to deaf persons: Some preliminary findings. In: W. Zagler (ed.): Proceedings of the 3rd International Conference on Computers for Handicapped Persons. Wien/München: R. Oldenbourg 1991, pp. 480-488.
10. G.W.G. Spaai: Teaching intonation to deaf persons through visual displays. In: B.A.G. Elsendoorn, F. Coninx (eds.): Interactive Learning Technology for the Deaf. Nato ASI Series F, Volume 113. Berlin: Springer Verlag, pp. 151-163.
11. H. Levitt, K. Youdelman, K. Head: Fundamental Speech Skills Test. Colorado: Resource Point Incorporation 1990.
12. S. Tahta, M. Wood, K. Loewenthal: Age changes in the ability to replicate foreign pronunciation and intonation. Language and Speech 24, 363-372 (1981).