A Study of Speech Prosody of Subjects with Profound Hearing Loss Recorded at Child Age and 20 Years Later

Ryszard Gubrynowicz

Institute of Fundamental Technological Research,
Polish Academy of Sciences, Warsaw, Poland
Ryszard.Gubrynowicz@ippt.gov.pl

Abstract

The aim of the present work was to test the comprehension and production of prosodic events by prelingual deaf children trained in oral communication with reference to several groups of control subjects (hearing-impaired, normal hearing ones). The recorded database children speech contains several lists of sentences of different linguistic form and function. The most developed studies concerned the group of profoundly deaf children after 5 years of regular oral language education by a new experimental method without the use of sign language. This group recorded these lists of sentences at the end of the education and 20 years later at adult age. The analysis was aimed at the tonal level of the speech and its temporal parameters. The main question was whether it is possible to teach deaf children to correctly control the prosodic inflections of F0 and the variations of segmental duration. The results of education were verified at adult age, 20 years later and they indicate that this group of profoundly deaf subject are still able to reproduce correctly the pitch contours as they result from the phonosyntactic models of Polish intonation. The speaking rate at adult age is shorter than it was at child age. This results from 20 years of practice using speech for communication.

1. Introduction

The large majority of deaf children achieve linguistic abilities that severely impair their academic and vocational achievement [1]. The overriding consequence of prelingual deafness is a dramatically lessened ability to acquire language at a rate and level that is consistent with the expectations and demands of society. The principal reason for this low achievement is the dramatically reduced amount of language input and hence of language competence brought on by hearing loss at precisely the time when the brain is most ready to take advantage of such information [2]. One of the very important features for comprehension of speech is prosody.

Many studies have shown that intonation information is a crucial component of the intended meaning conveyed in spoken language, and thus variations in pitch range can indicate topic changes. Moreover, a control of the appropriateness of prosody is important to obtain normal sounding speech. The present study is focused on the acoustic investigation of deaf children's ability to correctly reproduce pitch contours, after 5 years of regular oral language education and verification of their skills in controlling prosody at adult age. Some reference groups of normal hearing, hearing-impaired and deaf children (educated by traditional method) were formed to compare the intonation contours reproduced by school children having different hearing characteristics.

2. Subjects

This preliminary study, was focused on the comprehension and production of tonal events and tested in several groups of hearing-impaired and deaf children with reference to a control group of normal hearing subjects. All children knew that statements are pronounced with falling tone, sentences functioning as questions have a rising contour and vocative or imperative sentences are characterised by a sharp fall at the end. The first recordings were made with a group of 34 children - 6 profoundly deaf children (of ~10 years old, hearing loss >90 dB) after 5 years of regular oral language education by a new experimental, interactive method without the use of sign language, 9 profoundly deaf children of similar age, also after 5 years of language instruction, but by traditional method based on a combination of sign and oral education, 10 hearing-impaired children (hearing loss between 45-75 dB) and a reference group of 9 normal hearing children (10-14) years old.

The experimental group was created in 1975 and composed of six deaf children. Their normal hearing families wanted the children to talk and acquire the communication and social competence needed to succeed in regular education, without the use of sign language. During the preliminary period, the teacher used different ways to communicate with deaf children, like natural gestures, acoustic non-speech signals, pictures etc. She trained them in lip reading too, to achieve non-limited teacher-child communication. Their training was carried on at home by parents who continued speech perception and production exercises with them. From the very beginning the children were trained with special attention to teaching them how to control prosody in an appropriate manner [3]; the smallest unit they learned to pronounce was the word as a whole. This involves proper rhythm, tempo, accent, intonation and stress. More details about the education method are in [4].

3. Recorded texts

All the children recorded several lists of sentences grouped as declarative without supplement, declarative with supplement, wh-questions (mainly one-word), interrogative sentences without wh-words, imperative sentences, a sequence of one-word (of two-, three- or four-syllables) sentences spoken in contrasting mood. Each list was composed of ten items. The speech material was supplemented by a recording of reading aloud of a short, commonly known Polish children's verse ‘’ The lazy boy’’ by J. Brzechwa (Len’). This consisted of eleven sentences of which seven are rhetorical questions.

About 20 years later, some of the subjects who took part in the first recordings were asked to again record the same speech material. Taking part in this session were the complete experimental group of six profoundly deaf subjects, two profoundly deaf subjects educated in traditional manner, and one normal hearing person. All recordings are described, labelled and the information related to hearing losses with corresponding audiograms of the speakers are included in the digital database made for further studies on deaf children's speech.

4. Results

At the first stage of our study the analysis was focused on the tonal level of the speech of deaf children trained in oral communication by experimental method and of their speech at adult age. Some references were made to the results obtained for other groups of hearing impaired speakers. The main reference data are inferred from read speech of normal hearing children and include pitch contour characteristics defined by prompted texts to be read. Thus, the first step of analysis was to compare the intonation contour shapes and to investigate whether hearing-impaired and deaf children in the production of declarative, interrogative and imperative sentences employ them correctly. In particular, the set of one-word sentences uttered in sequences in three different moods shows clearly whether the speaker is able to correctly apply intonation function to sentence type disambiguation, as the intonation slope contrast is the only clue for sentence type distinction. The results indicate that this test was the most difficult for deaf, as well for some of hearing-impaired children.

5. Acoustic measures

The recorded material was processed by a script program written for this task and running in the Praat shell [5]. Special attention was given to automatize pitch tracking and graphic representation of the results of measurements on both an Hz and semitone scale. On the basis of the pitch contour measurements for every analysed utterance a tonal range was evaluated. This parameter calculated as the difference between maximal and minimal values of the analysed pitch contour was applied to assess the child's ability to modify the speech intonation in according with the sentence type to be pronounced. Syllable durations were also analysed. On the other hand, all recordings were listen by a musician having perfect pitch and he transcribed in the musical scale the melodic contours of spoken phrases (see Fig. 1). This subjective evaluation of deaf speech melody will be applied in intended studies on the perception of deaf speech.

The direct comparison of melodic curves is not very suitable to evaluate the similarity of recorded pitch contours. The first difficulty comes from differences between the mean fundamental frequencies for voice recorded at large time intervals, or for different voices. The second problem is due to different speech tempo for the same item.

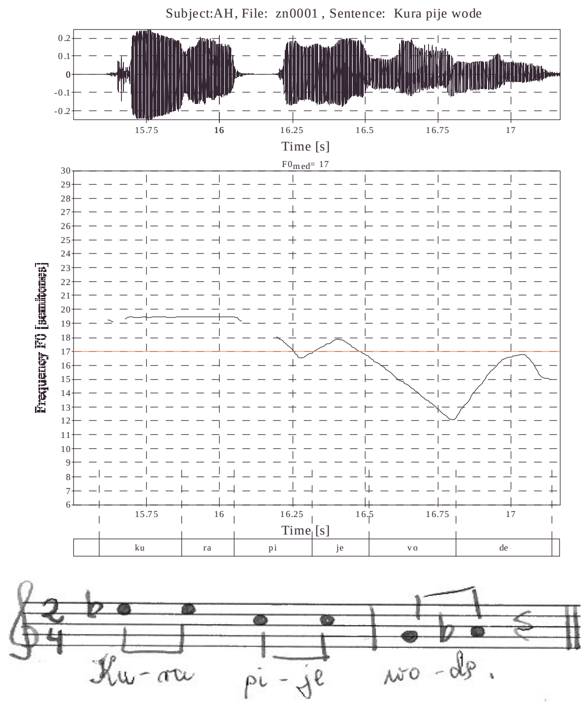

Figure 1 :Time evolutions of the stylized pitch contour (mid) measured (in semitones with reference to 100 Hz) for the 3-words sentence “Kura pije wodę” spoken by a profoundly deaf boy (AH). At bottom is presented the melodic transcription of the sentence made by a musician with perfect pitch (the real range of musical transcription is one octave down).

Thus, to compare two pitch contours of a sentence uttered by different persons or by the same person with a certain lapse of time, two kinds of normalization were applied: one for a speech tempo to obtain the same time duration for the items to be compared and the other for eliminating the influence of mean F0 frequencies (which move up or down the whole pitch contours).

The Fig.2 presents two normalized pitch contours of the same one-word interrogative sentence produced by a normal hearing girl (DA) and profoundly deaf boy (AH) recorded after 5-year oral speech education. To evaluate the degree of similarity of pitch contours, a presentation of pitch distance was applied in form of a curve drawn in a plane with two axes: one with DA time-stamped values (x-axis) taken as reference and the other to be compared (AH) with corresponding values on y-axis. In case the pitch contours are identical, all points of the curve should be distributed on the diagonal line of the plane.

The picture presented in Fig. 3 shows distinctly which parts of the analysed intonation contours are similar, and what kind of discrepancies are to be observed. The monotonous beginning of the intonation contour of AH is quite opposed to the slowly running down pitch of DA. But, after that the curve follows the diagonal falling down and next rising up remaining almost all time within ±2 semitones from the diagonal line. This distance limit applies to normal hearing subjects and is to be considered as just noticeable

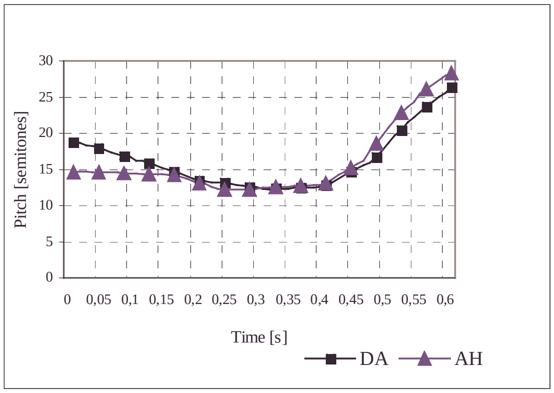

Figure 2 Time evolutions of the time and frequency normalized pitch contour for the one-word question "Pijemy?" (/pijemI) spoken by a normal hearing girl (DA) and a profoundly deaf boy (AH).

difference for F0 variations in speech; only pitch movements of more than 3 semitones are relevant for speech communication [6]. The trend line drawn on the figure does not differ much from the diagonal line. This means that the shapes of the compared curves are very similar. The mean distance between two curves (DA and AH) calculated from the distances determined at regular time intervals is about 1.4 semitones.

The picture shows not only the variation of the distance between pitch contours (represented by the distance of the plot from the diagonal line), but at the same time it is possible to observe the pitch evolution of the utterance spoken by one speaker with reference to the other. Such presentation of the results of comparison could be also applied to pitch control training in oral speech education of deaf subjects.

The next two figures (Fig. 4 and 5) show the results of comparing pitch evolutions made for the one word sentence spoken in affirmative mood by a normal hearing (AT) and a profoundly deaf subject (AH), both recorded at child age (Fig. 4) and 20 years later (Fig.5). From these figures it is evident that the shapes of compared pitch contours are similar, though for these measured at child age the pitch variations of the deaf boy (AH) are smaller than those of the normal hearing subject (AT). The shape of pitch contours measured for both speakers at adult age are very similar.

This method of the shape comparison of pitch contours may be also applied to various voiced items uttered with the same mood. It was observed that almost all subjects, especially at child age, had difficulties in controlling well the sloping downwards pitch curve of the sentences uttered in affirmative mood, but at adult age most of them managed to produce the pitch contour in accordance with the phonosyntactic models of Polish intonation.

This approach of analyzing the conformity of pitch contours is effective, especially, for short voiced utterances. For longer utterances with unvoiced segments, the time linear normalization is not appropriate and can be applied only to voiced parts of the speech signal. It seems that for longer utterances, a detailed analysis of syllabic durations and phrase accents must be done to formulate non-linear rules of pitch and time normalization .

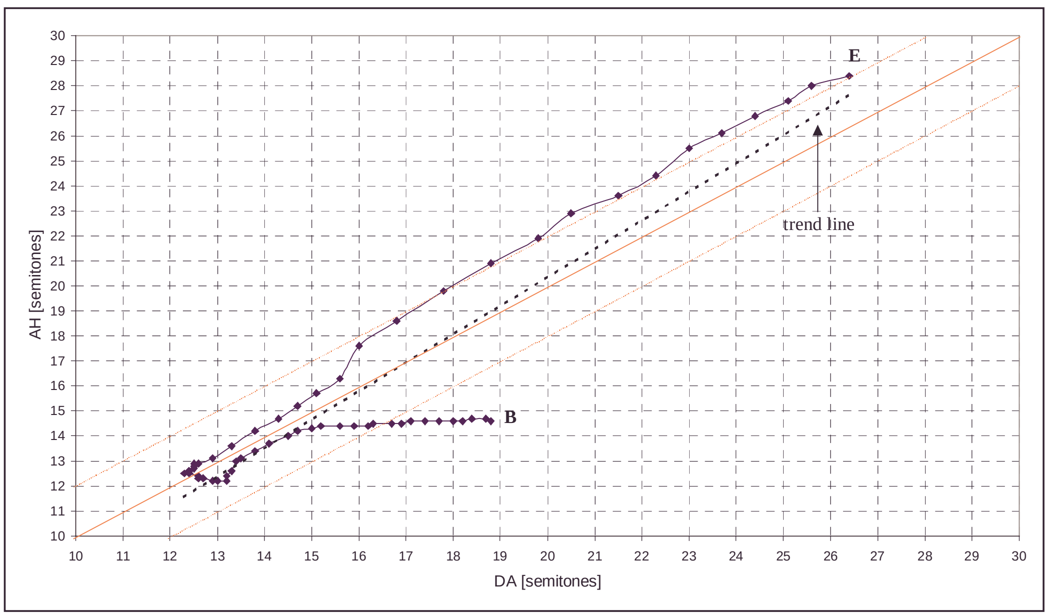

Figure 3: Time evolution of distance between pitch contours of one-word question "Pijemy?" spoken by a normal hearing girl (DA) (from the reference group) and a profoundly deaf boy (AH). The initial and final points of the curve are indicated by B and E, respectively

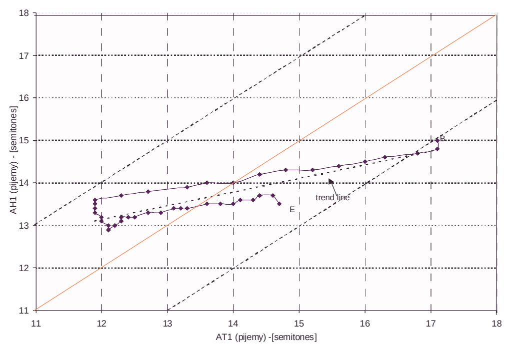

Figure 4: Time evolution of distance between pitch contours of one-word question “Pijemy” spoken in affirmative mood by a normal hearing subject (AT) and deaf subject (AH) recorded at child age.

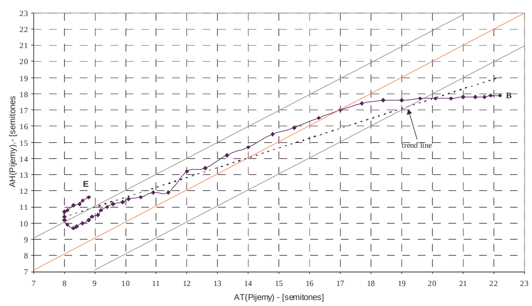

Figure 5: Time evolution of distance between pitch contours of one-word question “Pijemy” spoken in affirmative mood by a normal hearing subject (AT) and deaf subject (AH) recorded 20 years later.

6. Concluding remarks

The presented approach is appropriate to evaluate the similarity of the pitch contour of an utterance produced by a deaf subject to the reference contour produced by a normal hearing subject. The result of analysis is given in a form of diagram plotted on a plane with two axes; one corresponding to reference utterance, the other to utterance to be compared.

The present study focused on the evaluation of the ability of profoundly congenitally deaf children to learn correct reproduction of pitch contour. Their skills were verified 20 years later, at adult age. In most cases the deaf subjects maintained their ability to speak fluently with a good control of pitch slopes. However, it is worth noting that the most difficult phrases for the subjects to speak with correct pitch contours are those with falling slopes, i.e., sentences that should be spoken in affirmative mood, especially, declarative sentences with supplement. It seems that the perception of pitch falling slopes is not as well as rising ones. In accordance with t’Hart results [6] normal hearing people evaluate falling slopes of the pitch contour not so well as rising ones. Similarly, it was observed for deaf subjects that they managed to control better the rising than falling pitch contours and maintain a normal range of the pitch movement.

At present it is difficult to say how the residual hearing activated during oral speech education is integrated into the control of pitch movements. However, the ability to control pitch movements learned at child age is preserved at adult age.

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