Intelligibility test of hearing impaired Greek adolescents

PITA, R., PAPADOPOULOU, K. & KIOSSEOGLOU, G.

Department of Psychology
Aristotle University of Thessaloniki, Greece

ABSTRACT
The present study aims a) to investigate, register and analyse the special characteristics of the articulation of the hearing impaired and deaf population in Greece, and b) to create an intelligibility test of their speech. The intelligibility test, its principles, the way of its application and the required levels of reliability and validity of the test are presented in this study.

INTRODUCTION
Everyone who deals with deaf or hearing impaired people is not surprised when the speech of a child with hearing disorders, while comprehensible to the experts’ skilled ear, as well as within the family or the school environment, proves to be very or even completely unintelligible in everyday encounters. Differences in the intelligibility of both deaf and hearing impaired people, as noted by both skilled and unskilled listeners vary from totally comprehensible to absolutely unintelligible and less-than-perfect intelligibility is anticipated as an absolutely normal phenomenon, same by the casual listener as by the most specialised scientist (McGarr, 1983). Thomas (1963) points out that the exposure and familiarization to the speech of deaf/hard of hearing people are determinant for its comprehension, regardless of whether the listener belongs to the work or family environment of subject person or not. Research by Brannon (1966), Markides (1980) and Smith (1975) showed that unskilled listeners could make out one out of five words in the speech of the test population, while skilled listeners scored much higher. Also, comprehensibility percentages of most listeners skyrocketed when words were recited in full phrases rather than having the subject produce words which were not connected in meaningful sentences (Hudgins, 1949, Subtelny, 1977, Thomas, 1963). According to the literature (Markides, 1983, Morton, 1994) some 15 to 20% of the speech of the deaf is

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1 The study is a research project work of both the English Department and the Department of Psychology, Aristotle University of Thessaloniki, under the title: “Articulation variety in hearing impaired Greek adolescents: a study through the use of the electropalatograph (EPG) on speech disorders of hearing impaired populations compared to the speech of populations with normal hearing”.

generally understood by listeners in intelligibility tests. On the other hand, the articulation ability of deaf people (and therefore the comprehension of their speech) is seriously hindered, as a result of limited or zero exposure to lingual stimuli. The international literature shows that the articulation of the deaf is characterised by movements of the articulation organs which significantly deviate from the normal speech production of people with normal hearing. In addition, the sounds produced with articulated movements, which are not visible (for instance the back velars), tend either to be absent from the language of the deaf, or rarely reach the degree of accuracy achieved by healthy population (Dodd, 1976, Huntington et al., 1968, Markides, 1983, Crystal, 1997). The categorization of articulation deviations has showed that deaf people produce consonants less accurately than they do for vowels (Geffner & Rothman Freeman 1980). The omission of consonants is one of the most frequent mistakes recorded, mainly the omission of the back phonemes (Subtenly, 1977, Oller et al., 1978, Markides, 1983). Instant phonemes such as /p, t, k/ are replaced by fricatives such as /f, Ө, ܚ/ and complexes such as /kt, kl/ are simplified to instant sounds (Hudgins & Numbers, 1942, Oller et al., 1978, Calvert & Silverman, 1983, Morton, 1994). Another frequent phonological act is the alteration of the back phonemes into front bilabial or dental ones (Calvert & Silverman, 1983, Fletcher & Hasegawa, 1983, Barry, 1994). The research has also showed that the speech of deaf population is characterised by an extended variety in the phonemes’ articulation, as well as by a non-systematic production concerning the place and the way of their articulation (McGarr & Lofqvist, 1982, Dagenais & Critz-Crosby, 1991, Fletcher, Dagenais & Critz-Crosby, 1991, Crawford, 1995). These serious lingual disorders are due to the lack of acoustic feedback and the results of these disorders are of paramount importance in the communicative process.

INTELLIGIBILITY TEST - HISTORICAL RETROSPECTION
All previous research on intelligibility tests converges to certain points.
-Skilled listeners understand more of the speech of the deaf.
-Articulated vocalizations of the hard-of-hearing appear to be more comprehensible than these of the completely deaf people, which actually means that the quality of intonation and accent depend on the percentage of the remaining hearing ability.
-The more the degree of loss of hearing ability increases, the less intelligible the deaf speaker becomes, provided no substantial intervention has been applied in the direction of the facilitation of articulation and/or the achievement of everyday communication of the subject population.
-As subjects grow older, they try to achieve better quality in their articulation, resulting in increased intelligibility.
Contemporary technological advances in the area of hearing devices decisively contribute to the amelioration of the comprehensibility of the speech of the users.

Proportionately, full-scale intervention in early youth provides the deaf people with increased articulation and intelligibility.

The socio-economic level of both the family and the wider environment decisively contributes to the communicative dexterity.

Higher IQ does not seem to affect the perception of speech.

The educational system (oral and/or sign language, lip-reading and the holistic approach) influences the degree of intelligibility, with relevant superiority of the oral approach.

Acceptance and communicative behaviour of the healthy listeners directly affects the communicational ability of the subject population.

METHODOLOGY

PARTICIPANTS
Six youngsters, aged 15 to 16 (average 15.6 years old) participated in the research. Their acoustic ability levels vary as follows: 61 – 80 dB, one subject, 81 – 100 dB, three subjects, > 101 dB, two subjects.

The involvement of all participants was voluntary and subject to parental approval. 100 listeners of normal hearing, between the ages of 20 and 60 (average 42.5 years), of which 40 were skilled listeners, either working in schools, institutions and other rehabilitation facilities, or relatives and/or friends, well exposed to the speech peculiarities of the deaf. The remaining 60 listeners had no similar experiences until the day of the specific intelligibility test. All of them had perfect hearing, were native speakers of Greek and possessed normal IQ scores. Their participation in the research was voluntary.

INSTRUMENT

The intelligibility test structure followed the standards of the literature mentioned above, while at the same time it conformed to the features of the Greek language. The phonemes studied are mainly: [t, d, k, g, m, n, s, z, tʰ], front and back consonants, which the deaf cannot articulate easily and especially the back consonants, which do not have a visible articulated process. Also, the two basic vowels [a], neutral, low and open and by development the first in the course of acquisition of child speech and [i], front, high, close and spread vowel.

The articulation test was a battery of individual tests consisting of:
18 real words, with simple phono-tactic structure, of two syllables each.
29 disyllable words containing a diphthong (e.g. [ks, ps]) or a consonant complex (e.g. [str]).
5 sentences with alliterations, such as: [to klima ine sto ktima me ton kipo], [i t'ixla kolise sto t'igino tasaki] etc.

All subjects heard and then repeated all above mentioned words from the predefined protocol sheet. The examination took place in the laboratory of the School of English of the Aristotle University of Thessaloniki and the data were recorded on chromium tape and then digitised and recorded as sound (WAV) files into a multimedia equipped PC.

PROCESS
During the test the researcher plays out the sound files for the listeners, leaving adequate time between the sound reproductions, so that every normal hearing person can take down the word he has heard- or thinks he has heard. The order of file playback has been randomised before the test and all listeners are exposed to the same sequence. During the test, the listener graded the intelligibility of each sound file on a five scale grading sheet.

The following five-grade scale of perception was followed, according to which the recorded speech of the deaf is characterised as: perfectly comprehensible, easily comprehensible, quite easily comprehensible, semi comprehensible, hardly comprehensible, completely unintelligible.

The present research showed that the articulated vocalization of deaf people is assessed by the skilled and unskilled listeners with normal hearing as shown in the following table:

<table>
<thead>
<tr>
<th>Intelligibility</th>
<th>skilled listeners</th>
<th>unskilled listeners</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subjects/ N</td>
<td>Average</td>
</tr>
<tr>
<td>Perfectly comprehensible</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Easily comprehensible</td>
<td>5</td>
<td>93,2</td>
</tr>
<tr>
<td>Quite easily comprehensible</td>
<td>7</td>
<td>78,9</td>
</tr>
<tr>
<td>Semi comprehensible</td>
<td>10</td>
<td>52,4</td>
</tr>
<tr>
<td>Hardly comprehensible</td>
<td>9</td>
<td>31,9</td>
</tr>
<tr>
<td>Completely unintelligible</td>
<td>8</td>
<td>6,8</td>
</tr>
</tbody>
</table>

Only a single skilled listener scored 100% at the intelligibility test, and the unskilled listeners seemed to have more difficulty in discerning the speech of
the subjects. An interesting point to mention is that the levels of the
deafness, influence directly the speakers’ intelligibility scores, as shown in
table 2.

Table 2. Speakers’ intelligibility scores & deafness levels

<table>
<thead>
<tr>
<th>Speech</th>
<th>Deafness levels dB</th>
<th>Skilled listeners</th>
<th>Unskilled listeners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfectly</td>
<td>61 – 80 dB</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Comprehensible</td>
<td></td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Easily</td>
<td>81 – 100 dB</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Quite easily</td>
<td></td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>Comprehensible</td>
<td>&gt; 101 dB</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Semi</td>
<td></td>
<td>6,8</td>
<td>4,4</td>
</tr>
<tr>
<td>Hardly</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completely</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unintelligible</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Also, comprehensibility percentages sky-rocketed when the subjects produced words separately not connected in meaningful sentences, rather than the words were recited in full phrases.

Below, an attempt will be made in order to pinpoint the relation between the intelligibility of a word and the position of the articulation mistake(s) within the word. As shown in the table below the errors at the beginning of the word(s) deteriorate intelligibility, an effect which fades when mistakes occur at the end of words.

Table 3. Most frequent categories and nature of articulation errors

<table>
<thead>
<tr>
<th>Categories and nature of articulation errors</th>
<th>Speech intelligibility</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ERRORS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vowels &amp; diphthongs</td>
<td>-0,67</td>
<td>-0,70</td>
</tr>
<tr>
<td>Initial consonants</td>
<td>-0,86</td>
<td>-0,89</td>
</tr>
<tr>
<td>Final consonants</td>
<td>-0,88</td>
<td>-0,86</td>
</tr>
<tr>
<td>All consonants in word</td>
<td>-0,90</td>
<td>-0,88</td>
</tr>
<tr>
<td>NATURE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omissions</td>
<td>-0,76</td>
<td>-0,74</td>
</tr>
<tr>
<td>Substitutions</td>
<td>-0,40</td>
<td>-0,38</td>
</tr>
<tr>
<td>Phonetic distortions</td>
<td>-0,08</td>
<td>-0,08</td>
</tr>
<tr>
<td>Word distortion</td>
<td>-0,68</td>
<td>-0,86</td>
</tr>
</tbody>
</table>
The categorization of articulation deviations has showed that deaf people produce consonants less accurately than they do for vowels (Geffner & Rothman Freeman 1980). The omission of consonants is one of the most frequent mistakes recorded, mainly the omission of the back phonemes (Subtenly, 1977, Oller et al., 1978, Markides, 1983). Instant phonemes such as /p, t, k/ are replaced by fricatives such as /f, ð, x/ and complexes such as /kt, kl/ are simplified to instant sounds (Hudgins & Numbers, 1942, Oller et al., 1978, Calvert & Silverman, 1983, Morton, 1994). Another frequent phonological act is the alteration of the back phonemes into front bilabial or dental ones (Calvert & Silverman, 1983, Fletcher & Hasegawa, 1983, Barry, 1994). The research has also showed that the speech of deaf population is characterized by an extended variety in the phonemes’ articulation, as well as by a non-systematic production concerning the place and the way of their articulation (McGarr & Lofqvist, 1982, Dagenais & Critz-Crosby, 1991, Fletcher, Dagenais & Critz-Crosby, 1991, Crawford, 1995). These serious lingual disorders are due to the lack of acoustic feedback and the results of these disorders are of paramount importance in the communicative process.

Finally, it should be stressed that half of the subjects had been exposed to oral education, resulting in significantly more intelligible articulation ($p < 0.5$).

**DISCUSSION**

According to the results of this research, a plethora of factors affects the intelligibility of speech of the deaf people, such as the percentage of loss of hearing, the lingual environment in which the children grew up, the methods of communication and education adopted, the degree of familiarity with the speech of the deaf people by their normally hearing listeners, the dexterity of lingual use and ‘exploitation’ of its suprasegmental elements by the deaf people, the receptivity and communicative behaviour of the normally hearing listeners, the technological aids used etc.

The perception scores of the skilled listeners prove to be clearly higher than the scores of the unskilled listeners, which is predictable mainly because of their experience and exposure to the particular speech of deaf people. On the other hand, the inexperienced ear of the unskilled listeners forces them to try and guess the words of the deaf people (McEvoy et al., 1999, Soto-Faraco & Sebastián-Gallés, 2001).

In addition, both skilled and unskilled listeners alike, displayed higher scores of speech perception in single words, even higher than the intelligibility scores of complete sentences. A possible interpretation of this phenomenon is the small number of deaf participants, the structure of the tests and maybe even the random listeners’ sample. The large number of
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single words produced by deaf people relatively to sentences, possibly explains the higher intelligibility scores of single words versus sentences. It is obvious that the more articulation mistakes are produced the harder the perceptive process is accomplished. The mistakes in the final phonemes affect less the perceptive ability of the normal hearing listeners, as the information they receive concerning the phonetic, the morphological and the semantic structure of the words they hear and should comprehend increases. On the other hand, the articulation deviations in the beginning of words hinder intelligibility, due to inadequate information of lingual and prosodic elements (Word et al., 1994).

Another factor, which decisively contributed to speech intelligibility, is the use of technological aids. Deaf youngsters used to wearing hearing devices produce more comprehensible speech, as opposed to deaf people who never used any hearing devices in their life, resulting in poorer articulation dexterity. Additionally, the lingual intervention that deaf people received since their early childhood, undoubtedly provided them with stronger ability in articulation and hence intelligibility. Their lip-reading and oral training contributes to the best possible communication skills.

This pilot research aiming to create an intelligibility test of the speech of the deaf is an all-time first attempt in Greece, however it has not yet been completed. As it has been found, various factors contribute to the intelligibility of their speech. Some of them were assessed and studied in this project, such as the skill of the listeners, the level of hearing loss, the phenomena of coarticulation and suprasegmentals, the education the deaf has been subjected to etc., parameters which are valid for the specific research population (deaf and healthy listeners). Undoubtedly, the communication of deaf people is a two-sided “coin”: On one side deaf people themselves set the perception percentage of their speech using hearing devices, lip-reading, checking their articulation ability and receiving speech-therapy intervention. On the other side, normally hearing people decisively affect communication quality through their positive attitude, interaction and feedback, accumulating the maximum possible experience through maximum possible exposure to the speech of deaf people, also being receptive and encouraging.

REFERENCES


Markides A. (1980). Best listening levels of hearing-impaired children. *Journal of the British Association of Teachers of the Deaf* 4, 190-197


