A NEW COMPUTER-BASED ANALYTICAL SPEECH PERCEPTION TEST FOR PRELINGUALLY DEAF CHILDREN AND CHILDREN WITH SPEECH DISORDERS

Anne-Marie Öster

Department of Speech, Music and Hearing
KTH, Stockholm, Sweden
annemarie@speech.kth.se

ABSTRACT
A computer-based analytical speech perception test for early diagnosis has been developed. The test seeks to evaluate the ability to perceive a range of sound contrasts used in the Swedish language. The test is tailored for measurements with small children and low verbal children by using easy speech stimuli, words selected on the basis of familiarity, and pictures that represent the test items unambiguously.Prelingually hearing-impaired children with pure-tone averages worse than 90 dBm show very different results in the speech clinic. Their possibilities to develop intelligible speech have shown to be unrelated to their pure tone audiograms. The development of this test is an effort to find a screening method that can predict the ability to develop intelligible speech. The test is also intended to be used with small children, from 4 years of age, with difficulties to perceive and produce spoken language. The information gained from this test will hopefully provide supplementary information about speech perception skills, auditory awareness and speech intelligibility potentials and specify important recommendations for individualized speech-training programs.

1. INTRODUCTION
There are several speech perception tests in English that can be used with profoundly deaf children and children with specific language impairment (SLI) to assess their speech processing capabilities; the GASP test [1], the Merklein Test [2] and the Malthby Speech Perception Test [3]. Results from these tests have shown that this kind of testing gives a lot more information in terms of education and habilitation than the audiogram and the articulation index, as it indicates a person’s ability to perceive and to discriminate between speech sounds [3]. However, no such tests have so far been developed in Swedish for use with small children with difficulties to perceive and produce spoken language.

The development of the analytical speech perception test, described in this paper, is an effort to comply with the big need for early diagnoses and supplementary information to the pure tone audiogram about speech perception skills, auditory awareness and speech intelligibility potentials of prelingually and profoundly deaf children as well as of children with difficulties to perceive and produce spoken language. The expectation is that the result of this test will give important recommendations for an individual treatment and speech-training program.

2. THE RELATIONSHIP BETWEEN SPEECH INTELLIGIBILITY AND RESIDUAL HEARING CAPABILITIES
Several studies have shown that there is a positive correlation between the amount of residual hearing, as measured by better-ear average of pure-tone hearing threshold levels (PTA) at 500, 1000 and 2000 Hz and the intelligibility of the speech of hearing-impaired speakers in general. This is however not the case with prelingually and profoundly deaf children. The intelligibility of the speech of children with pure tone averages above 90 dBHL vary from poor to rather good due to the fact that some have hearing capabilities that are vibrotactile rather than auditory. Pure-tone audiograms cannot differentiate “vibrotactile” from “auditory” children. Vibrotactile perception is mostly limited to speech-envelope features like duration and intensity. Auditory perception identifies also spectral features like small differences in fundamental frequency and vowel formant patterns.

Figure 1: Rated intelligibility compared to hearing level of prelingually hearing-impaired children.
This has been shown in an unpublished study where the intelligibility of prelingually and profoundly hearing-impaired children’s speech from the 8th grade of the Manilla- and Alviksschool in Stockholm was investigated. The intelligibility of the children’s speech was rated as intelligible (3), intelligible without difficulties (2), intelligible with difficulties (1), or unintelligible (0).

In figure 1 it is shown that, on the average, speech intelligibility decreased with increasing hearing loss until a loss of about 90 PTA dBHL. Above that, the degree of correlation was reduced. Several studies have shown that pure-tone audiograms on the whole are poorly related to the speech intelligibility of profoundly deaf children. In a study by Öster [4] low correlations were found between pure-tone averages and speech intelligibility of eleven prelingually and profoundly deaf children, see fig. 2.

The purpose of the study was to find out if there was a measure of residual hearing that could predict a deaf child’s ability to develop intelligible speech. Correlations were made between speech intelligibility scores and amount, quality and use of the children’s residual hearing.

Hence, the sort of speech a profoundly hearing-impaired child develops depends not only on the amount of hearing, as measured by PTA, but also on the quality of the hearing sensation and the use the child through training has been able to make of his/her residual hearing.

Speech processing capabilities are usually measured through psycho-acoustical tests, which give good informations about a person’s ability to perceive temporal and spectral features of speech. However, such tests are inappropriate to use with small children. Speech processing capabilities are of course more appropriate to measure by means of a speech-test especially designed for this group. The results of the second experiment are presented in Figure 4. They are generally quite similar to the results of the first experiment and thus do not show a great influence of the visual cues.

**3. DECISIVE FACTORS FOR SPEECH TESTS WITH SMALL CHILDREN**

The aim with an analytical speech perception test is to investigate how sensitive a child is to the differences in speech patterns that are used to define word meanings and sentence structures [6]. Consequently, it is important to use stimuli that represent those speech features, which are phonologically important. Since the speech reception skills in profoundly deaf children is quite limited, and since small children in general are low verbal, the selections of the speech material is crucial. The words selected must be familiar and meaningful to the child, be presented in pictorial form and contain the phonological contrasts of interest to assess. To present sound contrasts as nonsense syllables, so that the perception is not dependent on the child’s vocabulary, is however not a solution. It has been shown that nonsense syllables tend to be difficult for children and that they often substitute the nearest word they know [3].
Other important factors to pay attention to are:

- order of difficulty of stimuli presentation
- which are the familiar words for children at different ages and with different hearing losses
- what is the most unambiguous way to illustrate the chosen test words

Moreover, the task must be meaningful, natural and well understood by the child, otherwise he/she will not cooperate. Finally, the test must rapidly give a reliable result, as small children do not have particularly good endurance and motivation.

4. TEST CONSTRUCTION

In the development of this analytical speech perception test the above mentioned decisive factors were taken into consideration.

The test is developed within Microsoft Power Point. By using the option “Slide Show”, values for presentation can be preset. The test contains illustrated easy and familiar words of minimal contrast. The words contain important phonological Swedish contrasts and each contrast is tested in one of twelve different subtests. In Table 1 a summary of the test shows the phonological contrasts tested in each subtest, an explanation of the discrimination task and one example from each subtest.

Figure 4. An example of the presentation of test stimuli on the computer screen. In this case the phonological contrast of vowel quantity is tested through the words buss-bus [bus-bus] (bus-mischief)

The words used were recordings of one female speaker. An illustrated word is presented to the child on a computer screen together with the female voice reading the word. The task of the child is to discriminate between two following sounds without illustrations and to decide which one is the same as the target word, see figure 4. The child answers by pointing with the mouse or with his/her finger on one of the boxes on the screen.

The result is presented in % correct responses on each subtest showing a profile of a child’s functional hearing.

Figure 5 shows an example of varying profiles of three tested children. Child 3 is a normally hearing boy with SLI, who had problems with temporal discrimination (subtest 6). Child 2 is a hearing-impaired preschool child with a pure tone average of 50 dBHL, who got high scores on all subtests. Child 1 is from a deaf school in Stockholm and his pure tone average was in the vicinity of 90 dBHL. This child had difficulties with low frequency discrimination and failed to discriminate between nasals and voiced/unvoiced consonants, voiceless/voiced consonants and between vowels differing in low frequencies.

Confusion matrices are also shown where all errors can be analysed. Such results are useful for the speech therapist for diagnostic purposes and give good indications of the child’s difficulties in perceiving and subsequently producing the Swedish language.

This analytical speech test is now going to be further evaluated by several children of different ages and different levels of hearing-impairments as well as by normal hearing children with special language impairment (SLI) to test the reliability and validity.
<table>
<thead>
<tr>
<th>Subtest</th>
<th>Speech feature tested</th>
<th>Discrimination</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Surrounding sounds</td>
<td>Time and intensity differences</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Fundamental frequency</td>
<td>Male/female/child voices</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Gross discrimination of long vowels</td>
<td>F1 and F2 varying in frequency</td>
<td>ba/bi</td>
</tr>
<tr>
<td>4a</td>
<td>Discrimination of voiced consonants</td>
<td>Low to high frequency voicing</td>
<td>amma/ajja</td>
</tr>
<tr>
<td>4b</td>
<td>Discrimination of voiceless consonants</td>
<td>Energy varying from low to high frequencies</td>
<td>appa/assa</td>
</tr>
<tr>
<td>5</td>
<td>Number of syllables</td>
<td>One syllable/polysyllables</td>
<td>bil/brandbil</td>
</tr>
<tr>
<td>6</td>
<td>Vowel quantity</td>
<td>Long/short vowel</td>
<td>tiger/tigger</td>
</tr>
<tr>
<td>7</td>
<td>Discrimination of vowels</td>
<td>Vowels differing in low frequencies</td>
<td>fot/fat</td>
</tr>
<tr>
<td>8</td>
<td>Discrimination of vowels</td>
<td>Vowels differing in high frequencies</td>
<td>sil/sål</td>
</tr>
<tr>
<td>9a</td>
<td>Nasality</td>
<td>Voiced consonant/nasal</td>
<td>läsa/näsa</td>
</tr>
<tr>
<td>9b</td>
<td>Nasality</td>
<td>Voiceless consonant/nasal</td>
<td>fyra/myra</td>
</tr>
<tr>
<td>10</td>
<td>Manner of articulation</td>
<td>Transient/continuous</td>
<td>tåg/såg</td>
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<tr>
<td>11a</td>
<td>Place of articulation</td>
<td>Voiceless consonants</td>
<td>sol/kjol</td>
</tr>
<tr>
<td>11b</td>
<td>Place of articulation</td>
<td>Voiced consonants</td>
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<tr>
<td>12a</td>
<td>Voiced/voiceless consonants</td>
<td>Same place of articulation</td>
<td>buss/puss</td>
</tr>
<tr>
<td>12b</td>
<td>Voiced/voiceless consonants</td>
<td>Different place of articulation</td>
<td>bok/fot</td>
</tr>
</tbody>
</table>

Table 1. The twelve subtests included in the test.

5. ACKNOWLEDGEMENTS

Special thanks to speech therapists from Audiology Clinics and Rehabilitation- and Habilitation Centres in Stockholm for valuable collaboration and discussions. This work has been supported by grants from KK-stiftelsen.

6. REFERENCES