Verification of a Set of Speech Perception Tests for Children with a Cochlear Implant

Jolanta Bachan

Instytut Językoznawstwa UAM

ul. Międzychodzka 5 , 60-371 Poznań

jolabachan@op.pl

ABSTRACT

This article concentrates on the results of the project work aiming at the verification of a set of speech perception tests for children with a cochlear implant created at Adam Mickiewicz University in Poznan. The article outlines the key criteria for creating speech perception tests for children with normal hearing or children with hearing impairment and what children demand from such tests. The key to the success is attractiveness, intelligibility and modelling a dialogue between a child and a computer. Without these the child has to count on someone to help him or her understand the talking device.

1. Speech perception tests

In the process of communication hearing is as important as the ability to speak. People usually speak for the purpose of communication with others who receive the acoustic signal. This signal must be decoded and then understood by the hearer. This is why the study of speech perception is one of the major applications of phonetics. In order to explore this area of research phoneticians developed different kinds of tests involving labelling and discrimination. Many of these tests make use of synthetic speech which allows to present carefully controlled speech-like stimuli to listeners in order to obtain simple judgements on their perception [1].

The set of speech perception tests created at Adam Mickiewicz University is designed for children with a cochlear implant. Tests for this young population are difficult and it should be taken into account that besides being hearing-impaired, the subjects are scared, impatient and get bored quickly. During the last few months the set of speech perception tests was verified and it was discovered that the tests did not allow for children's requirements. It was found out that the tests had to undergo many changes to

meet children's needs. It was important to render the tests attractive and intelligible and to model a dialogue between a child and a computer. These three factors are the key to success in any speech perception tests for children. Without these the child has to count on someone to help him or her understand the talking device.

2. The hearing mechanism

Hearing involves peripheral and central processing. Peripheral processing is carried out in the ear itself, central processing takes place in the cortex. The ear consists of three sections: the outer ear, the middle ear and the inner ear. All three sections work together to deliver sound information to the brain where it is interpreted as hearing.

The outer ear collects sound and sends it down the ear canal into the middle ear. The sound waves bounce off the ear drum and are amplified by three tiny bones: the hammer, anvil, and stirrup. The sound waves travel into the inner ear. The inner ear is comprised of two main parts: the cochlea which contains the intricate hair cells and the vestibular system which controls balance. The inner ear is filled with fluid. When the waves from the middle ear reach the fluid in the inner ear, the fluid starts to move. The waves go through the cochlea, where tiny hair cells pass on the vibration of the sound and turn it into electrical energy. The electrical impulses are transferred to the auditory nerve fibres and sent through the auditory nerve to the brain where they are interpreted as sound [2].

3. Testing cochlear implants

3.1. What is a cochlear implant

A cochlear implant is a small, complex electronic device that can help to provide a sense of sound to a person who is profoundly deaf or severely hard-of-hearing. The implant bypasses the outer and the middle ear functions and directly stimulates the remaining auditory nerve fibres in the inner ear. The electrical sound information is sent form the auditory nerve fibres through the auditory system to the brain. The brain recognises this as sound, which results in hearing sensation.

The cochlear implant consists of an external portion that sits behind the ear and a second portion that is surgically placed under the skin. An implant has the following parts [3]:

- A microphone, which picks up sounds from the environment,
- A speech processor, which filters and digitizes sounds picked up by the microphone into coded signals and sends these electrical sound signals through a thin cable to the transmitter,
- A transmitter, which is a magnetic pad placed behind the external ear, and transmits the processed sound signals to the internal device by electromagnetic induction,

- A receiver/stimulator secured in bone beneath the skin, which receives signals from the speech processor, converts them into electric impulses and sends them through an internal cable to electrodes,
- An electrode array, which is a group of electrodes that collects the impulses from the stimulator and sends them to different regions of the auditory nerve.

An implant does not restore or create normal hearing. Instead, it does improve the person's ability to hear environmental sounds, to hear rhythms and patterns of speech, and to use lip reading better.

3.2. Testing implants vs. testing the tests

Testing implants and testing the tests are two separate areas of research. The first area is concerned with the evaluation of the cochlear implant efficacy. The evaluation task is based on the properties of the cochlear implant and the effect of these properties on perception and understanding by the subject. The second area of research evaluates the level of efficiency, ergonomics, motivation and suitability for the subject. This article is concerned with the second area of research.

3.3. Specification of the speech perception tests

The set of speech perception tests for children with a cochlear implant is composed of tests with verbal stimuli. The tool tests children's perceptive and linguistic skills making use of acoustic signal only. There are no visual cues, so the subject cannot lip-read.

3.3.1. What the tests examine

In the following section there is a list of the most vital tests from the set of speech perception tests for children with a cochlear implant [4].

Identification of disyllabic words of structures: ***cvcv*** (np. woda), ***cvccv*** (np. łóżko), ***cvcvc*** (np. banan), ***ccvcv*** (np. klucze), ***ccvcvc*** (np. sweter). It this test synthesised stimuli are used. All the stimuli have flat fundamental frequency.

Identification of unstressed syllables. The aim of this test is to assess the ability of identifying mono- and disyllabic words pronounced separately differing in the unstressed syllable only. E.g. *król – królik*, *kran – ekran*.

Identification of voice. The aim of this test is to recognise speaker's voice. The male, female and children's voice is used. The child responds by pointing out the proper picture of a man, a woman or a child.

Identification of segmental characteristics – vowels and consonants. The aim of this test is to differentiate and to identify individual vowels or individual consonants in different contexts of a word. The test material is composed of minimal pairs - pairs of words that differ in one phoneme only.

E.g. for vowels: *m**a**ska - m**i**ska*, *b**a**t – b**u**t*, for consonants: *ła**p**a – ła**t**a*, ***b**eczka – **t**eczka*.

Identification of segmental characteristics in words and logatoms. The aim of this test is to examine the perception of segments of speech. The test material is composed of minimal pairs. Minimal pairs are arranged as follows: a word with meaning vs. a logatom (a word without meaning), e.g. *bałwan (a snowman) – pałwan*.

Memorisation of units. The tests examines the auditory memory. A given number of verbal stimuli is presented and the subject has to point at the pictures corresponding to the stimuli in the same order as they were heard.

Memorisation and identification of linguistic structure. The aim of this test is to assess the ability of making use of the contextual and syntactic information in combination with segmental information in perceiving simple sentences. The test material consists of sentences of the same structure – the subject, the predicate and the object.

Recognition of phrases - Pan Ziemniak (Mr Potato). The aim of this tests is to recognise individual words in a phrase which begins always the same. In the three steps of the test the subject is asked first to draw Mr Potato's parts of his body, e.g. stomach or legs. In the next step the subject dresses Mr Potato. The subject is asked to put on Mr Potato e.g. gloves or shoes. Finally, the subject is asked to give Mr Potato different things, e.g. an umbrella or a balloon.

Recognition and intelligibility of complex phrases. The aim of this test is to assess the ability of recognising and comprehending speech by pointing at the correct key word. The tests are designed for children who are able to comprehend speech in open sets but who are unable to take a test requiring verbal responses. The tests are composed of lists of simple questions. In order to answer the question the subject point at the correct picture among three presented on the computer screen.

Recognition and comprehension of continuous speech - a battery of thematic tests are designed for children who are able to comprehend speech in open sets but who are unable to take a test requiring verbal responses. In these tests the child does not have to hear precisely each part of the sentence, but he or she should be able to reconstruct the content of the speech.

3.3.2 The functional requirements specification

The equipment needed for conducting the tests:

- a computer with Windows software,
- speakers,
- a touch screen OR a computer screen and a computer mouse.

The tests were implemented as a set of programs running on Win32 platform, built in Borland C++ Builder environment. All data, i.e. images and sounds (more precisely: their names) are stored in simple databases to allow quick modification to each of the tests without source code changing.

3.3.3. Ergonomic properties

The set of tests for children with a cochlear implant is composed of tests at different levels of difficulty and different tasks are assigned to the subject. The tester chooses only the appropriate tests for the testee, so that not to tire the little subject of going through all the tests. Moreover, in case the subject is getting bored, the tester can assign a new task to regain the subject's interest. The tester can stop the test at any time and go to the next one.

To facilitate the testers' work each of the tests has a simple statistic function built-in. The statistics shows the percentage of correctly recognized stimuli and the number of presented stimuli in the test. Unfortunately, the whole set lacks a database which would store the subjects' results. In the present version of the set of tests, the tester has to write down each of the results on a paper or save it somewhere else.

The tests are designed for young children and it was taken into account that not every child knows how to use a computer mouse. To avoid this kind of obstacle the tests were designed to be used with a touch screen. In case there is no touch screen the tests can be taken using a computer mouse. During the process of verification of the tests it was found out that children as young as four years old had the command of using the computer mouse and could successfully take the test.

3.3.4. Intelligibility

The set of speech perception tests is designed for children with a cochlear implant. It has to be stressed that for this population of testees all the unnecessary difficulties should be avoided. In order to create intelligible speech perception tests **the instructions** have to be easy and understandable to the subject. Because the development of children's hearing and their linguistic skills depends on personal features and goes differently for every child, tests on different levels of difficulty have to be designed. Furthermore, **the pictures** used in the tests should math the stimuli. There cannot be any doubts about what kind of an image the picture illustrates. Finally, **the sounds** used in the tests have to be correctly recorded and have to be of the highest quality. The best way to avoid problems connected with speakers' pronunciation is to use synthesised speech in speech perception tests.

3.3.5. Attractiveness

Attractiveness is the key to success in any test for children no matter whether the test is designed for children with normal hearing or for children who are hearing-impaired. Firstly, the test has to attract the child's attention. Graphics is the most important here and the designers should invest in it. Secondly, if the child gets interested in doing the test, the designers should plan how to fuel this interest. To reach this aim the designers should prepare

different kinds of tasks and render the tests lively in order to avoid monotony.

Although the plan seems easy, it is not easy to achieve the aim. In the set of tests the designers invest in the pictures that show real images. It is assumed that the subject may learn what the real world looks like from the images presented in the test. Unfortunately, this does not boost attractiveness from the children's point of view. Children want to watch cartoon-like images rather than the mundane ones.

3.3.6. Dialogue modelling

Communication between a human being and a computer is a field of research of many scientists. In a speech perception test where a child has to interact with a computer, it is vital to model a dialogue between these two subjects. Firstly, the child has to know what the computer wants him to do. To achieve this the instructions to the tests have to be clear and understood by the subject. Secondly, the computer has to show the child that the child does exactly what the computer expects him or her to do. Namely, if the child's response is correct, the computer has to illustrate that the answer given is correct. The child cannot have any doubts that his or her actions are correct or incorrect. Thirdly, the computer has to convince the child that he wants the child to play with it more and make the child stay at the computer longer. This target can be achieved only by introduction of a very good positive reinforcement. The reinforcement has to be attractive and unpredictable. The designers of tests for children should take it to heart.

4. Method: administration of the tests

The set of speech perception tests is designed for children with a cochlear implant who are able to comprehend speech, but who may be unable to give verbal responses. The method is designed for use by audiologists and speech therapists. It can be used to help the audiologist program the cochlear implant or as an achievement test by the speech therapist. The set of speech perception tests is also perfect teaching material and, beside speech therapists, it can be used by parents to help their children work on their perceptive skills.

Each of the test is composed of two parts: the teaching module and the test. In the teaching module the subject is familiarised with the content of the tests. The subject can hear all the verbal stimuli used in the test and associate them with the pictures which simultaneously appear on the screen with the sounds. This part of the test is designed to be used as teaching material. The second part is the test itself. The instructions are provided and the child responds using a touch screen or clicking on the appropriate picture using a computer mouse. This part of the test presupposes that the subject knows the content or at least is able to recognise most of the verbal stimuli. The test assesses the subject's perceptive and linguistic skills.

5. Verification and results of tests

The set of speech perception tests was verified on two groups of children. The first group consisted of children with normal hearing: 14 four-year-olds, 21 five-year-olds and 22 six-year-olds. The second group was composed of 15 children with a cochlear implant. The children were at different ages. The youngest children were 2,5 years old, the oldest children were 11. All the children were born deaf or lost their hearing before their speech was developed. Only one of the children lost her hearing after acquiring a good command of speech.

As far as equipment requirements are concerned, a computer with Windows software, an ordinary graphics and an ordinary sound card is appropriate for running the tests. Additionally, speakers of ordinary quality can be used. Furthermore, the use of a touch screen is very helpful. Children do not have to know how to use a computer mouse to take the tests. However, if there is no touch screen available, children can take the tests using the mouse. Children as young as four years old took the test successfully using the computer mouse.

Cooperation with children with normal hearing and children with hearing impairment showed similarities of needs of these two groups of children. Both groups were interested in the task and willingly took part in the tests. Although they were a bit scared at the beginning, they easily came to like the tests. However, children with normal hearing treated the tests like a play and children with a cochlear implant treated the tests as another serious test of their hearing abilities.

All the children expected from the tests to be attractive and dynamic. They got bored quickly if the test was monotonous. It also turned out that children preferred cartoon-like images to those illustrating the real images. Some of the verbal stimuli were not recognisable by the subjects. Although ordinary speakers were used in the testing procedures, the problem did not lie in the quality of speakers, but in the quality of pronunciation, namely, how precisely the speaker uttered a word or a sentence used in the test. When the speaker pronounced a word or a sentence very quickly, both groups of children had to listen to the recording more than once. In many cases children searched for a sign of confirmation from the testers or their parents to make sure that the picture they had chosen was correct before clicking on it, which proves the fact that the strategies modelling a dialogue between the subject and the computer should be improved. As far as children with a cochlear implant are concerned, they were eager to get very good results in the tests. If they were unable to recognise the verbal stimuli, they looked at their companion (a tester, a parent or a speech therapist) in order to read the word from their lips. If such an opportunity was given to the children, it encouraged them to listen to the sounds more carefully and try to recognise the cues without lip-reading.

The children understood the task and willingly did the tests. The correctness of responses of children with a cochlear implant was higher

when they heard the cues more than once. Those children who were in a hurry or lost concentration did not do well in the tests. That result was not caused by the their impairment, but by children's spontaneity and liveliness.

6. Conclusion

The set of speech perception tests for children with a cochlear implant is a perfect research tool to evaluate children's language development. It can be used as teaching material for cochlear implantees to learn sounds that surround them, but are rarely heard in isolation. Nevertheless, the designers of the tests have to look more carefully at children's needs and introduce some modifications. The most important problem to be solved now is how to boost attractiveness and minimise the number of people taking part in the testing procedure. At present three subjects are needed: the child, the computer and one additional human being who helps the child understand and communicate with the computer. The perfect state of affairs would be if that second human subject was eliminated. If that aim was reached, the child could take the test thinking that he or she was playing a computer game and all the results would be automatically stored in a database for future processing by audiologists and speech therapists.

References

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