A set of speech perception tests for children after cochlear implants – preliminary evaluation

tytuł po polsku poproszę...

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ABSTRACT

Congenital sensorineural hearing loss occurs approximately in 2 per 1000 newborns and results in significant and often irreversible retardation in the development of speech and language. Early detection is possible thanks to universal hearing screening programs. They are administered throughout the United States and in other countries all over the world. This results in the fact that the age of identification of hearing loss has been reduced to within the first few months of life. This article introduces one type of such hearing screening programs that contains exercises composed of hearing tests at different levels depending on child's age and the degree of hearing loss. The article discusses pilot verification of this research tool when applied to a population of Polish children by testing chosen variables, e.g. segmental perception of speech sounds and their indicators, e.g. detection of phones and discrimination of isolated phones, etc. The tests were implemented as a set of programs running on Win32 platform, build in the Borland C++ Builder environment. All data, i.e. images and sounds (more precisely: their names) are stored in simple databases to allow quick modification of each of the tests without changing the source code. A common graphics module is developed to provide several visual effects, e.g. alpha-blending, rotating and zooming to make all tests more attractive.

STRESZCZENIE

po polsku poproszę...

1. Introduction

Congenital sensorineural hearing loss occurs approximately 2 per 1000 newborns and results in significant and often irreversible retardation in the development of speech and language. Early detection is possible thanks to universal hearing screening programs. They are established throughout the United States and in other countries throughout the world. This results in the fact that the age of identification of hearing loss has been reduced to within the first few months of life. This article introduces one type of such hearing screening programs that contains exercises composed of hearing tests on different levels depending on child's age and the degree of hearing loss. The article is a trial of verification this research tool on the population of Polish children by testing chosen variables, e.g. segmental perception of speech sounds and their indicators, e.g. detection of phones and discrimination of isolated phones, etc.

The most significant predictors of speech intelligibility among children with mild through profound hearing losses are: 1) language development and 2) degree of hearing loss. Screening programs and tests can freely check these two predictors (Yoshinaga-Itana & Sedey, 2000). The benefit of screening programs (especially in the case of newborns) has been that children with moderate and severe hearing loss are now similar in both speech and language production to children with mild hearing loss.

Screening programs are needed both in the selection of cochlear implant candidates and the evaluation of cochlear implants. Supraliminal features of hearing are discrimination and identification of sounds. Tests for discrimination or identification of words exist, but especially in the preverbal child the results are strongly biased by their individually variable language impairment or cognitive skills. A "preverbal" child is a child with no or very limited functional speech both comprehensive and productive. Tests for this "preverbal" population are difficult and should be conceived in such a way that the dependence on the child's linguistic and cognitive skills is minimal and that no reading and speech skills are required. Furthermore, the distinctive features should be very clear and unambiguous so as not to leave any doubt which features are perceived by the child and which are not. At least some of the tests should provide the fitter with phoneme-based analytical information to guide the fine-tuning of the cochlear implant.

A common way to investigate auditory performance is the identification test. Identification tasks presuppose a degree of linguistic knowledge and higher functions that are not always present in the hearing impaired child. Thus most of the existing identification tests are only fit for verbal children.

Another and possibly more correct way to test preverbal children is testing discrimination instead of identification. In that case the child has to discriminate between two or more successive stimuli (such as phonemes) and has to show behavioral response.

It is felt by many professionals in the field that cochlear implants could have significant impact on the speech and language development if they could be implanted at sufficiently young age, meaning before the onset or at a very early stage of the linguistic development. Detailed longitudinal studies of speech perception, speech production and language acquisition have justified a trend toward cochlear implantation at young ages. This suggests that early implantation yields significant advantages in children's ability to encode, process and produce spoken language compared to age-matched peers who were implanted at later ages. Early-identified children (within the first six months of life) have

better speech intelligibility (Appuzo & Yoshinaga-Itano, 1995; Yoshinaga-Itano, Coulter & Thomson, 2000), better language development and vocabulary knowledge (Appuzo & Yoshinaga-Itano, 1995; Yoshinaga-Itano, Coulter & Thomson, 2000), better social-emotional development (Yoshinaga-Itano, 2002), and better emotional availability.

SOME OTHER AUDIOLOGICAL PROCEDURES USED HITHERTO THAT MAY BE INCLUDED IN EVALUATING CHILDREN'S HEARING

- **Conventional Audiometry.** In this type of hearing test for children, the audio-logist presents speech sounds and pure tones at different pitches and loudness levels. The child is required to respond to the softest tones heard and to repeat words (or point to pictures of words).
- **Behavioral Observation Audiometry (BOA).** In this type of hearing test for infants, the audiologist closely observes the infant's behavior and facial expressions to determine when he or she hears sounds that are presented through speakers. The audiologist is well trained to recognize such behaviors that might include changes in sucking patterns, widening of the eyes, or searching for the source of the sound. This type of test must be used in conjunction with other supporting tests.
- **Visual Reinforcement Audiometry (VRA).** In this type of hearing test for infants and young children, the audiologist directs the child's attention toward a toy that lights up and moves when the child looks in response to a sound. This type of test is typically used for infants and children ages six months to two years.
- **Play Audiometry.** During this test, the audiologist teaches the child to respond with some play action, such as putting blocks in a container or building a chain, whenever he or she hears a sound.
- **Tympanometry.** This test measures the movement of the eardrum and the ability of the middle ear to conduct sound to the inner ear. It is usually performed along with **otoacoustic emissions** and/or **acoustic reflexes**.
- **Acoustic Reflexes.** In a normal-hearing ear, the stapedius muscle in the middle ear contracts in response to loud sounds presented at levels of about 70–100 dB (decibels). In this test, the audiologist presents tones at these levels and determines whether the child has an acoustic reflex and what level of sound is required to produce the reflex.
- **Otoacoustic Emissions (OAE).** With this test, a probe in the ear canal measures sounds created by the inner ear in response to sounds presented by the audiologist. If the response is absent, a hearing loss may be present.
- **Auditory Brainstem Response (ABR).** For this test, sensors are pasted and taped on the child's head to measure and record the brain's direct response to sound. Because the child does not have to actively response to the sounds, it is often used with infants and very young children. It can even be done when the child is asleep.

2. Speech perception tests for children

The program created in Poznań is dedicated to infants and young children. The method is designed for use by audiologists using modern audiometers which can be controlled by a computer. The instructions and visual reinforcements are provided and

the child responds using a touch screen. The instructions are presented in a training module that determines if the child understands and responds appropriately.

2.1. The preliminary level

The preliminary level (for the youngest, one-yeard-old children) of preverbal tests designed to assess the ability of perceiving synthetic sounds is composed of tests:

For the variable of the segmental perception of speech sound:

Detection of phones. The aim of this test is to assess the ability of perceiving different phones pronounced continuously. The test material consists of phonemes including synhtetic vowels and selected consonants. Phone's space includes the whole frequency range. Different phones with different acoustic parameters (Fo, formants) are generated simulating male, female and children's voice.

The basic test version includes: **i a u m sz**. The complex version consists of vowels: **i y e a o u**, nasal consonants and liquids: **m n l r** and fricatives: **f w s sz ż**.

During the test the phones are uttered by a speech therapist or they are generated by a computer. In the test 15 pictures of a dwarf are used imaging the phones. The result shows the percentage of phones heard.

Discrimination of isolated phones. The aim of this test is to assess the ability of discriminating different phones pronounced continuously. The test material consists of phonemes including synhtetic vowels and selected consonants. Phone's space includes the whole frequency range. Different phones with different acoustic parameters (Fo, formants) are generated simulating male, female and children's voice of identical intonation.

The basic version includes pairs of phones: **u-i i-a a-u z-s m-z s-sz v-z u-l y-l u-y m-r**. The complex version is composed of a dozen of different pairs of phones, e.g. **z-r u-sz o-a u-o e-a i-e y-i z-ż m-n r-l ...**

In the test 15 pictures of a dwarf are used imaging the phones. The result shows the percentage of phones heard correctly and incorrectly.

For the variable of the suprasegmental perception of speech sound:

Discrimination and identification of quantity. The aim of these tests is to discriminate or identify the quantity of vowels. During the test synhetic syllable **be** is generated with different acoustic parameters (Fo, formants) simulating male, female and children's voice, the vowel **e** has three different lengths: the short **e** (50 ms), the medium **ee** (100 ms) and the long **eee** (150 ms). Pictures of a short, a medium and a long sheep are used imaging the duration of the vowels.

Discrimination and identification of rhythm. The aim of these tests is to discriminate or identify rhythm. During the tests four signals are generated: lenghty **o** and three synthetic syllables: **hop hop hop hop hop hop** with different acoustic parameters (Fo, formants) simulating male, female and children's voice of identical intonation. Pictures of a plane and a kangaroo jumping on the stairs are used.

Discrimination and identification of quantity and rhythm. The aim of these tests is to discriminate or identify quantity and rhythm. During the tests three synthetic syllables are generated: **hop hop hop hop hop hop** with different acoustic parameters (Fo, formants) simulating male, female and children's voice of identical intonation. The basic frequency of synthesised intonations changes in the octave range.

E.g. for a male voice: **80 Hz – 120 Hz – 160 Hz**
160 Hz – 120 Hz – 80 Hz

Pictures of a kangaroo jumping up and down on the stairs are used.

Discrimination and identification of the amplitude. The aim of these tests is to discriminate or identify the amplitude. During the tests the synthetic syllable **bam** is generated with different acoustic parameters (Fo, formants) simulating male, female and children's voice of identical intonation and three levels of loudness: 50 dB, 60 dB, 70 dB. Pictures of a short, a medium and a tall dwarf are used imaging the loudness of the sounds.

For the variable of the segmental perception of phones in syllables:

Identification of perceptive space of vowels. The aim of this test is to define perceptive space of vowels of definite quantity in syllables with minimal coarticulation. The test material consists of isolated synhtetic syllables pronounced by male, female and children's voice with different acoustic parameters (Fo, formants). Six pictures of a dwarf are used imaging a particular syllable: : **hik hyk hek hak hok hut**. The result shows the array of identifications heard correctly and incorrectly and the map of vowel formatives F1 and F2 heard by the child.

Identification of consonants. The aim of this test is to assess the ability of identifying different syllables pronounced separately. In this test the manner and the place of articulation, voice/voiceless and the gradual perception VOT are taken into account. The test material includes synthetic phones pronounced by male, female and children's voice. A dozen different pictures of a dwarf are used imaging a particular syllable, e.g. **ba da, da ta, sza sa, bi-li, sa-sza**. The result shows the array of identifications heard correctly and incorrectly and the map of acoustic parameters accepted by the child.

2.2. The basic level

The basic level (for 2–3-year-old children) of verbal tests designed to assess the ability of perceiving natural speech is composed of tests with the variables of the segmental perception and the suprasegmental perception:

Identification of disyllabic words of structures: cvcv (np. szafa), **cvccv** (np. łóżko), **cvcvc** (np. banan), **ccvcv** (np. klucze), ccvcvc (np. sweter). For the younger group the test material includes 24 words from Polish frequency dictionary (12 sin-gular words, 12 plural words, 6 stressed vowels) pronounced by male, female and children's voice. Whereas the test material for the older children consists of 64 words from Polish frequency dictionary which include all Polish phonemes with **ą** and **ę** (with irregular pronunciation).

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. The test material consists of natural words of different meanings pronounced by male, female and children's voice, 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.

2.3. The medium level

The medium level (for 3–4-year-old children) designed to assess the ability of perceiving natural speech is composed of tests with the variable of the segmental perception and the suprasegmental perception.

Discrimination of rhythmic patterns and identification of words. The aim of the test is to examine the perception of rhythmic patterns in words of a different number of syllables (the perception of suprasegmental characteristics is required, i.e. quantity and intensity) and to assess the ability of identifying words (knowledge of spectral characteristics of phones is required). The test material includes groups of mono- and disyllabic words. Each group consists of six words of the same vocalic-consonantal **cvc**-structure and each word in the group has a different stressed vowel. For the test two reports are produced: the first one shows the number of words classified correctly to mono- or disyllabic groups of words, the second one shows correctness of identifications. E.g. for younger children: l**i**s r**y**ż j**e**ż r**a**k n**o**s b**u**t, whereas for older children: l**i**s grz**y**b j**e**ż kwi**a**t k**o**ń kl**u**cz.

Identification of segmental characteristics in trisyllabic words. The aim of this test is to assess the ability of identifying words (knowledge of spectral characteristics of phones is required). The test material consists of groups of four trisyllabic words with the same vowel, e.g. m**a**rch**e**wk**a** k**a**l**e**nd**a**rz g**a**z**e**t**a** ł**a**zi**e**nk**a**.

Discrimination of rhythmic patterns and identification of mono-, di-, tri- and four-syllable words. The aim of the test is to examine the perception of rhythmic patterns in words of a different number of syllables (the perception of suprasegmental characteristics is required i.e. quantity and intensity) and to assess the ability of identifying words (knowledge of in spectral characteristics of phones is required). The test material includes four groups of (1) monosyllables, (2) disyllables, (3) trisyllables and four-syllable words. Each group consists of six words of the same vocalic-consonantal structure **cvc** and each word in the group has a different stressed vowel. For the test two reports are produced: the first one shows the number of words classified correctly to mono- or di- or tri or four-syllable group of words, the second one shows correctness of identifications. E.g. the **cvc**-structure for monosyllables: lis mysz ser rak koń but; the **cvcvc**-structure for disyllables: lizak dywan zegar talerz rower wózek; the cvcvcvc-structure for trisyllables: pomidor korytarz telefon parasol samochód ogórek; the **cvcvcvcvc**-structure for four-syllable words: hipopotam kaloryfer telewizor kapelusik czekolada karuzela.

Identification of suprasegmental characteristics in two-word phrases. The aim of this test is to examine the perception of the place of stress in different rhythmic phrases. The test material includes short phrases composed of a subject and a predicate, e.g. Mama gotuje (Your mother is cooking). Tata sprząta (Your father is cleaning). Each phrase is read two times – in the first time with stress on the subject, in the second time with stress on the predicate. The child hears one of two phrases differing in the place of stress only. The child should choose one of two pictures illustrating: the subject (their mother, their father) or the activity (their mother cooking in the kitchen, their father cleaning the room).

Identification of suprasegmental characteristics in three-word phrases. The aim of this test is to examine the perception of the place of stress in different rhythmic phrases. The test material includes short phrases composed of a subject, a predicate

and an object e.g. Żabka skacze do wody. (The frog is jumping into the water). Each phrase is read three times – in the first time with stress on the subject, in the second time with stress on the predicate, in the third time with stress on the object. The child hears one of three phrases differing in the place of stress only. The child should choose one of three pictures illustrating: the subject (a frog) or the activity (a jumping frog) or the object (water).

Identification of segmental characteristics in words of minimal context – 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 pairs of words that make minimal pairs (words with similar meaning differing in one vowel or one consonant 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 of minimal contrast supported by visual information. The aim of this test is to assess the ability of differentiating and identifying individual consonants in different contexts of a word. The test material includes pair of words that make minimal pairs. The test examines: bilabial consonants, e.g. beczka – teczka, labial-dental consonants, e.g. furtka – kurtka, consonants **l** and **ł**, e.g. ławka – szafka, łóżko – uszko, defferentiation based on segmental information only, e.g. kula – kura.

Identification of segmental characteristics in words and logatoms. The aim of this test is to examine the perception of pairs of words differing in voiced/voiceless consonants. The test material is composed of pairs of words that make minimal pairs (words with similar meaning differing in one consonant only). Minimal pairs are arranged as follows: a word with meaning – a logatom (a word without meaning), e.g. bałwan – pałwan.

Perception of basic phonetic-acoustic structures of the Polish language. The aim of this test is to differentiate mono- and disyllabic words with the same consonant and of the same word structure (including words with the consonantal cluster). The test material is composed of 42 pairs of mono- and disyllables differing in meaning. The consonantal cluster is in the initial sound or in the final position. E.g. blok – lok, chmury – mury.

Identification of segmental characteristics in logatoms. The aim of this test is to differentiate and to identify individual consonants in different **cvc**-contexts. The test material includes from two to three thousand logatoms pronounced slowly by male voice. Groups of three words are classified according to the place of atriculation, the manner of articulation and the voice – **phonetic classification**. E.g. apapa, apipa, apupa.

2.4. The advanced level

The advanced level (for 4–5-year-old children) designed to assess the ability of perceiving natural speech is composed of tests:

For the variable of the auditory memory:

Memorization of linguistic unit. The aim of this test is to memorize long phrases and to segment a sound. The test material includes numbers 1, 2, 3, 4 and mono-, di- and trisyllabic words pronounced by male, female and children's voice. The child should point at the pictures in the same order as they were heard.

Memorization 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. All words in the test are disyllabic. 270 phrases are used. In the training module the child learns to associate the picture with the sentence heard. After memorizing the child should choose the correct picture imaging the sentence heard among six other pictures.

For the variable of the suprasegmental recognition:

Intonation of the question, intonation of the statement – verbs, adverbs, adjectives. The aim of this test is to differentiate the rising intonation from falling intonation, which means to differentiate the question from the statement. The test material is composed of phrases of simple structure of words from Polish frequency dictionary including nouns, verbs, adverbs and adjectives. To make the differentiation easier antonyms are used, e.g. śmieje się – płacze (sb is laughing – sb is crying), dobrze – źle (good – bad).

For the variable of the segmental recognition:

Recognition of phrases. The test is composed of three thematic tests: **dzień malucha** (a child's day), **poszukaj zwierzątka** (find the animal) and **pan ziemniak** (Mr Potato). The aim of these tests is to recognise known words of cvc- and ccvc-structure. On the pictures the child can see:

– a child's day – what a child does during the day, e.g. a child is washing his or her hands, face, teeth…;
– help the mother-animal find her child, e.g. Find a piglet, a chicken or a little dog in the picture…;
– Mr Potato – parts of the human body, clothes, e.g. Draw Mr Potato's head, stomach,…; Put on him a shirt, shoes, …; Give him an umbrella, a balloon,…

The program includes tests (for 4–6-year-old children) designed to assess the ability of speech recognition and speech intelligibility. In this kind of tests the variables concern recognition of words or phrases and intelligibility of simple and complex phrases.

Recognition of words. The aim of two versions of this test is to assess the ability of recognition of words.

In the first version the test material is composed of disyllabic words (i.e. the easy test which includes ten ten-word lists) and monosyllabic words (i.e. the complex test which includes seven ten-word lists). The child hears a word and he or she should choose the correct picture among those which are presented simultaneously with the sound.

In the second version the words concern one of the topics:

– A child's day 2.
– Mr Potato 2.

Memorization of units. This test examines auditory memory. The basic version includes a dozen or so orders of simple linguistic structure, e.g. Wrzuć do pierwszego kosza kota, klocek i psa. Do drugiego kosza wrzuć lalę, samochód i kredki. (Into the first box put the cat, the block and the dog. Into the second box put the doll, the car and the crayons.) The complex version includes a dozen or so units (orders) of complex

linguistic structure, e.g. Połóż książkę na stół, klocek pod stół, a kredki schowaj do szuflady. (Put the book on the table, put the block under the table and put the crayons into the drawer.)

Recognition and intelligibility of simple phrases. The aim of this tests is to assess the ability of recognising and comprehending speech by responding to the orders given. 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 orders. Each order should be preceded with the child's name. The task gives a positive result if the order is carried out correctly. E.g.

A. (the child's name) Podskocz dwa razy. (Jump up two times.)
B. (the child's name) Dotknij buta. (Touch your shoe.)
C. (the child's name) Pokaż język. (Put your tongue out.)

Recognition and intelligibility of complex phrases based on key words. The aim of this test is to assess the ability of recognising and comprehending speech by repetition. In this test the child repeats the phrases heard.

Recognition and intelligibility of complex phrases. The basic version consists of 20 phrases, the complex version consists of 65 phrases. The aim of these tests 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 which require pointing at the correct picture among three presented on the touch screen.

The program also includes tests designed to assess the ability of recognising and comprehending **continuous 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. In this test 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. Each of the sentences is illustrated by four pictures, one of which corresponds to the content of the sentence. The child should choose the correct picture among four presented. The test material includes a dozen or so sentences describing a certain situation:

a) Kasia is helping her mother.
b) Krzyś is hungry.
c) Jaś is sick.
d) Gosia's grandfather lives in the country.

3. Summary

Audiological procedures such as hearing screening programs and tests are essential tools in order to find out about children's language development and evaluation of cochlear implants. Tests introduced in this article give the opportunity of verification of the research tool that has not been used in Poland so far. The article is also a trial of popularization of this research tool.

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