THE ILLUSION OF PERCEPTUAL RESTORATION OF MISSING PHONEME IN CHILDREN.

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ABSTRACT

It was shown that 5-6 year old children perceptively restored a missing phoneme in a word more often than adults. Adults had the influence of the localization and the acoustic properties of the missing phoneme on the perceptive restoration but children had not. The children could seldom name the missing phoneme, but often they intuitively localized it correctly repeating the word with mispronounced phoneme in the right place.

Perceptual restoration of a missing phoneme (PRMPh) is the auditory illusion in which one hear a nonexistent part of a word [1]. In studies of the PRMPh the adults listen to the speech in which some segments are replaced by nonspeech signals and usually can not detect the missing segment, often perceiving the word with missing phoneme as intact. It was shown that with the adults the PRMPh depends on the acoustic characteristics of the phoneme and the replacing signal, phoneme localization, speech material [1,2]. The children's ability to restore the missing phoneme and the exploration of their PRMPh particularities were the purpose of our study.

Method.

Subjects. The participants were 20 children (10 boys and 10 girls from 5,2 to 6,0 years of age) and 20 adults (10 men and 10 women from 16,0 to 29,2 years of age). The subjects were native Russian speakers with no problems in hearing and speech. All children could not read but had some notion about "word" and "letter" and they knew some letters of the Russian alphabet.

Stimuli. All the test words were three-syllable ones and familiar for the children. The words were spoken clearly by a man and recorded on the audio tape. Then the words with the missing phonemes were constructed by a programmable signal analyzer (NEC, San-ei Ltd., Japan) using the procedure that had been described by Samuel [2]. The target phoneme was located visually on the word oscillogram on the analyzer display and auditorily over headphones. The determined phoneme was bracketed by two pointers and the digital root mean square amplitude (DRMSA) of its central 20 msec was computed. Then each point within the bracketed segment (10 kHz sample rate) was replaced with a random number between +DRMSA and -DMSA. The test words (intact and with a replaced phoneme) were recorded on audio tape in an occasional way. The main test consisted of 90 words, 30 of which were intact, 60 words were with a missing phoneme, the latter being: 20 - with the missing first consonant (stop or fricative), 20 - with the missing middle consonant, 20 - with the missing vowel (the second phoneme in the word, stressed or unstressed).

Procedure. The test stimuli were played to the subjects binaurally from audio tape over stereo headphones. The testing was individual. The nature of the stimuli had been explained beforehand. The adults were told that they would hear the words in some of which one of the letters (because as a rule they did not know what a phoneme is) was replaced by a noise. Their task was to repeat the word, to say whether the word was intact or not, and to name the missing letter or to determine its approximate localization in the word. That explanation was not clear for the children and they were told that they would hear "correct" and "incorrect" words with one "bad" letter. Their task was to repeat the word, to determine if it was "correct" or not, to name the "bad" letter or to say if it was at the beginning, in the middle or at the end of the word. The children mostly repeated strictly what they had heard. The subjects' responses were protocoled by the researcher. During the training session before the subjects were made to listen to each word they were told whether the word was intact or not and what phoneme had been replaced. Then the subjects listened to the words and answered without preliminary explanation. When the subject understood the task and his responses (whether the word was intact or not) were found to be not chance ones, the main test began.

Results and discussion

The children and the adults perceived the intactness of the words very well but the children had a slightly less number of correct responses (see Table). The subjects often failed to notice the absence of a phoneme in the word with a replaced phoneme and perceived it as intact, i.e. they perceptually restored the missing phoneme. With the children PRMPh was more frequent than with the adults. With the adults PRMPh was more frequent for consonants in the middle position than for initial consonants, least of all for vowels. With the children the influence of these factors were insignificant.

Samuel [2] had proposed to use the interactive schema theory by Rumelhart [3] for PRMPh explanation. In this theory the perceptual-cognitive system is viewed as a collection of active processing units. The units are data structures that are activated either by other processing units (top-down) or by incoming sensory information (bottom-up). The perceptual process is essentially an evidence-gathering task, perception occurs when a given schema has received sufficient evidence. The pieces of evidence can come from bottom-up and top-down sources. In general, the top-down information can be characterized as expectation and the bottom-up as confirmation. The PRMPh is an evidence for top-down processing of speech because it occurs more often for central phoneme where the initial part of the word helps to advance the correct hypothesis. The influence of the acoustic characteristics of the replacing

Table. The indexes of the different response types for children and adults (the ratio to the quantity of the stimuli of the accordant group in percents)

The types of responses	Children	Adults
The intact words		
1. "The word is intact"	90	96
2. "The word is not intact"	10	4
The words with a missing phoneme		
1. "The word is intact" (PRMPh) *	45	17
init. cons./mid.cons./vowel */*/*	49/54/36	21/32/1
2. "The word is not intact" *	53	83

The note: init. cons. - the indexes for the words with the replaced initial phoneme; mid. cons. - for the words with the replaced middle phoneme; vowel - for the words with the replaced vowel; * - for these indexes the differences between the children and adults are significant at level < 0.01.

sound on the PRMPh is an evidence for bottom-up processing.

However, the use of the interactive model is not enough for the explanation of our results. Actually, the greater number of PRMPh with the children must mean their greater use of "top-down" mechanism. However this does not agree with the fact that the influence of the missing phoneme localization was insignificant with the children. On the other hand it does not mean that the children have a more effective "bottom-up" mechanism because the influence of the phoneme acoustic characteristics (the replacing signals were perceived as noise and sounded rather like consonants) was insignificant with the children.

The analysis of the responses to words with the missing phoneme when the word distortion had been detected can help to explain the results. The identical responses with the adults and the children were: the correct and incorrect determination of a missing phoneme, the subject could not localize the missing phoneme in the word, the word was not understood. The children had a insignificant number (3%) of correct determinations of a missing phoneme. For both groups: the best determination was for initial consonants, the worst - for vowels. As a rule the children could not name the replaced phoneme (correctly or incorrectly) or indicate its approximate localization in the word. The adults detected a missing phoneme incorrectly in words with replaced vowels, they usually named the neighbouring (mostly preceding) consonant. The number of the words that the children did not understand was nearly the same as with the adults. As a rule the subjects did not understand the words with replaced vowels (mostly stressed). In that case the children gave another word, the adults - rather a pseudo word more often.

Moreover the children had two additional response types. In one type which was named as "the unconscious correct determination of the replaced phoneme" the children said that the word was distorted and then they repeated the word with the distortion of the corresponding phoneme. But they could not name isolated the phoneme that had been replaced. In the other type called "the word is distorted, but is understood" the children first mispronounced the word and then they pronounced the correct word . For example, one said "I heard [f'ufka] (the pseudo word), but it must be [d'evochka] (a girl)". These responses were characteristic for words with a replaced stressed vowel.

The data analysis suggested that the adults and the children have and may use various speech information. Apparently, children have a word description as a whole image which they mainly use in perception. "That description includes essential details and it is insensitive for local signal distortion. This provides for the effective perception of intact words and words with a missed phoneme (the number of non understood words was almost equal for both groups). Evidently, an intact stressed vowel is necessary for using this description, because its replacement prevented the comprehension of the word. Using word description as a whole image with significant details in perception makes it possible to detect the distortions in words. However, it is not effective for that purpose therefore the children showed the greater number of PRMPh than the adults. If it is necessary to localize the distortion, especially to name the distorted phoneme that description is not enough. Though the children could not name the replaced phoneme they actually perceived the distortion of the phoneme correctly repeating the word with the distortion of the corresponding phoneme. Apparently, the replaced phoneme detection requires the using of word description as a sequence of phonemes. 5-6 year old children do not

have it and we believe that this description develops with reading ability.

Nevertheless 5-6 year old children seemed to have some information about phonemes and its acoustic cues, because sometimes they named the replaced phoneme (usually incorrectly). Moreover, when the children said that the word was "incorrect" and then repeated it with distortion of the corresponding phoneme ("the word is distorted, but it is understood"). They imitated specific phoneme features: the replaced vowel was pronounced loudly and with a drawl, the voiced consonants - as voiceless ones. Besides the children as well as the adults perceiving the words with a replaced vowel considered that the neighbouring consonants had been replaced .

Adults have a word description as a whole image and as a sequence of phonemes. The latter are not used at normal speech perception because it requires much time. We suppose that adults and children use the word description as a whole image in processing in normal perception. If perception requires the use of phoneme description (in the test with PRMPh or another task requiring the phoneme analysis of speech) the adults use it together with the main whole image description singling out and identifing the word phonemes. But that analysis does not keep up with main processing based on whole image of word description which provides for the fast achievement of the principal purpose - word comprehension. This causes the effect of the PRMPh. The speech processing is interactive: the upper levels of the system advance a hypothesis about the incoming signal and require the necessary information from the bottom levels. This information is used for the hypothesis verification and correction as well as for the creation of new hypotheses. The final decision is taken when the hypothesis and the results of the analysis coincide, usually on the base of the particular information (sufficient in this situation). The interaction of top-down and bottom-up mechanisms causes the influence of the replaced phoneme localization and acoustic characteristics on the PRMPh. Apparently, the insignificant influence of these factors on the PRMPh and the pecularietes of children's responses mean that 5-6 years old children have not yet developed both these mechanisms and their interaction.

References

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