PHYSIOLOGICAL CORRELATES OF SPEECH-HEARING INTERACTION

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ABSTRACT

The electrophysiological and psycho-acoustical data depicted different levels of speech-hearing interactions. The first is a "input control filter" established as independent on the higher levels of auditory processing. It supports the constancy of auditory afferent flow during vocalization as well. The next level realizes mechanisms of reinforcement of auditory flow during vocal activity of a subject. The highest levels were described as reciprocally related with subcortical levels of auditory afferent flow processing.

INTRODUCTION

It is evident that the activity of auditory and speech producing systems of humans is interconnected and interdependent. Nevertheless it can be stated that up to the present time we have only scanty information on the structure and interaction mechanisms of the sensory and motor components of the auditory-speech function. The question about the influence of speech process as a directed motor action provided by the program of the central brain conducting links remains unsolved, though the interaction between hearing and speech presents two sides of one and the same communication process. It is obvious that the interaction of speech and hearing is due to the mutual feedback activity.

The aim of present study is to investigate the manifestations and levels of speech-hearing interaction by means of auditory potentials of different latencies evoked by test stimuli against the background of vocal speech activity of a subject.

METHODS

A.Subjects.

There were 19 subjects (males and females), aged from 19 to 50, participating in the study. All of them were healthy physically and mentally and had normal tonal audiograms both for right and left ear measured before the experiment.B.

Preliminary procedure.

All the experiments were carried out in the acoustically isolated electrically screened chamber. At the beginning of the experiment each subject was offered to sing a melody of a well known song, his mouth being closed. The intensity of a sound produced by the subject was self-selected and controlled by special device for the estimation of sound pressure with microphone, put at the distance about 10 sm. from the mouth. Usually the intensity of the song corresponded to 40 dB as compared to the intensity of wideband noise and that of the same song recorded at the magnetic tape. Both were presented to the subject through the earphones binaurally in the control series of the experiment as the control background sounds.

C. Acoustical stimulation.

The stimuli were: (1) test-stimuli clicks of 1 ms duration at the level of 40 - 50 dB above threshold; (2) sustained wide band noise of 40 dB above threshold; (3) self produced melody of a well known song; (4) the same song melody produced by the same subject recorded in the majority of subjects only at the background of noise.

2. P_2 and N_2 components (the place of generation is supported to be the thalamo-cortical auditory structures) can be recorded only at the background of the total acoustic influence. However, during the subject's song production, P_2 and N_2 components in response to test clicks increase as compared with the response to test signals without any background and decrease while listening a song from the tape-recorder or at the background of noise (as well as P_1 and N_1 components of LLAEP and MLAEP). Peak latent periods are changeable, there being a tendency to their increase at the background of all the acoustic background influence (song melody self-production, in listening the same melody as external sounds and in noise), though this tendency doesn't reach any significant values (the results for 9 subjects).

DISCUSSION

I. Thus, initial SLAEP waves evoked by test stimulus increase while at the background of listening to a song melody from the tape-recorder or to the background noise, but do not change, if the subject is vocalizing the song himself. Wave 5 of SLAEP can increase or decrease during subject's song production, but these changes are not statistically relevant. Therefore, an incoming afferent flow changes under the influence of external sounds, but remains unchanged at the background of subject's vocalization of song melody. It means that vocalization does not hinder external sound afferentation and the afferent flow is controlled by a "filter", decreasing the influence of the sounds vocalized by the subject. One can suppose that the mechanism which allows to produce vocal speech and to listen simultaneously to external sounds without their substantial distortions at the level of the auditory input is realized at the auditory periphery due to the activity of the feedback system from the vocalization centers.

II. The fact that waves of MLAEP evoked by test stimuli increase sharply at the background of song melody production and slightly increase or even decrease during listening to a tape-recorded song melody or in the background of noise, can be considered as an indication of vocal speech producing and auditory systems interaction. The interaction must be realized at the levels of midbrain and diencephalon and is directed to the reinforcement of an external signal, to its distinguishing at the background of the subject's own vocal activity.

Such a reinforcement mechanism contributes to the significance of the income information conservation process due to vocal-hearing control. The decreasing of some MLAEP waves, in the conditions of external stimulation (tape-recorded vocalizations and noise), shows a well-known phenomenon of masking one stimulus by another depending on physical parameters of the stimuli.

III. The increase of amplitude of N_1 P_1 and P_2 N_2 waves evoked by test-stimulus at the background of song vocalization and their decrease at the background of external acoustical stimulation completely repeats the phenomena related to the electrical activity of the subcortical brain structures. Accepting the viewpoint that the LLAEP waves reflect the activity of thalamo-cortical level one can believe that subcortical processes are directed to the reinforcement of afferentation evoked by external sounds at the background of the appropriate vocal-speech activity of a subject, in conditions of interference of two signals (both the test and the background ones) recorded and reproduced by the tape. Test stimuli (1) were presented without any background sounds or against the background stimuli (2), (3) and (4) in the successive series of electrophysiological recording of auditory evoked potentials.

D. Electrophysiological experiments.

Auditory evoked potentials (AEP) of various latencies from the vertex were recorded with the help of standard method. According to Picton et al., (1974) AEP were classified as (1) short-latency - SLAEP (PLP up to 8 ms); (2) middle-latency - MLAEP (PLP 8-40 ms) and long-latency - LLAEP(PLP 40-350 ms).

RESULTS

I. Short-latency potentials - SLAEP.

1. The amplitude of waves 1-4 (the place of generation - auditory nerve, cochlear nucleus, superior olivary complex, lateral lemniscus) weekly depends on all types of sounds, representing the background of test clicks. There is a tendency ($0,1>p>0,05$) for the wave amplitude increase at the background of sounds presented binaurally from the tape-recorder (a song melody) and from the noise generator (white noise). There were no amplitude differences in response to the test-stimulus before and during the reproduction of song melody by the subject. The peak latency periods of the waves evoked by the test stimuli at the background of different sounds did not change.
2. The amplitude of wave 5 (the place of generation - lateral lemniscus, inferior colliculus) increases weekly during the subjects song production, without the difference reaching any significant level in comparison with the reaction to test stimulus. At the same time, the increase of the amplitude of wave 5 at the background of a noise and of a song melody presented from the tape-recorder is statistically significant ($p<0,01$). The increase of the amplitude at the background of noise is observed to be higher than at the background of the song produced by the subject as well as presented from the tape (the data for 10 subjects).

II. Middle-latency potentials - MLAEP.

1. The amplitude of wave evoked by test stimulus with peak latency less than 20 ms (the place of generation being midbrain, probably inferior colliculus and diencephalon) at the background of the subject's song production increases sharply, being higher than at the background of listening the same song melody from the tape recorder and white noise. Peak latent period of some waves is decreased during subject's song production ($p<0,01$).
2. The amplitude of waves with peak latency of 20 ms or more (the place of generation is probably diencephalon and thalamic nuclei) behaves similar to the amplitude of other MLAEP waves. Their peak latent periods shortened during song generation and kept of the same value as in response to the test stimulus presented without background or against the background of listening to the song melody from the tape-recorder and to noise (the results for 7 subjects).

III. Long-latency potentials - LLAEP.

1. All the components of LAEP (P_1 N_1 , P_2 N_2 , P_3 N_3) can be distinctly recorded only in response to the test clicks. During the song production by the subject the components P_3 and N_3 disappear, being recorded in response to click not in all subjects and not regularly in one and the same subject. Similar results were also demonstrated during listening to the self-produced song melody presented from the tape. Masked and diminished in amplitude these components of LLAEP can be

at the auditory input, and possible mutual depression of afferent flow at the different brain levels, that reflects in the evoked potentials in response to external sounds and subject's vocal activity. Cortical components P_3 and N_3 of LLAEP behave differently in principle as they do not appear at all in the conditions of subject's own sound production. Cortical activity to external stimuli is depressed at the background of vocal speech activity. One can think that physiological filtration of the afferent flow is accomplished at the subcortical levels, where the afferent flow is distributed to the executive structures of the brain. The cortical generators of P_3 and N_3 components may be required for activation of some directed attention and only with its participation can reflect different properties of the afferent flow.

CONCLUSIONS

1. The interaction between vocal speech and auditory system is fulfilled at all levels of the brain and is depicted in amplitude value and shape as well as in latency of the auditory evoked potentials. Most evident are the interactions reflected at the levels of middle- and long-latency auditory evoked potential generators.
2. The waves of middle-latency potentials (electrical correlates of the midbrain activity, probably of diencephalon and thalamus as well) in response to the test signal are increasing at the background of vocal speech activity and decreasing at the background of external sound action.
3. The initial components of long-latency auditory potentials (P_1 N_1 , P_2 N_2) behave in the same manner as middle-latency potentials. The wave N_2 P_3 has reciprocal relations to initial waves, especially sharp differences being found at the background of the subject's own vocal speech activity.

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