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INTENSITY DISCRIMINATION OF THE SHORT HIGH-FREQUENCY STIMULUS IN FORWADR MASKING CONDITIONS

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In given work results of simulation and psycho acoustical experiments investigating properties of peripheral coding of fine amplitude-temporal structure and auditory intensity discrimination of high-frequency stimulus, presened in silence and after previous noise are shown. Coincidence of conclusions of the carried out experiments reveals connection between peripheral encoding and auditory intensity discrimination.

Simulation researches have been shown, that the short-term volley of the auditory nerve fibers (ANF) is capable to reproduce fine amplitude-temporal structure of short high-frequency stimulus only close to the detection thresholds of stimulus, whether irrespective of the stimulus in silence or noise [2]. If amplitudes of stimulus are higher, because of recovery process of the ANF excitability, the arising on-set response of the group ANF will not prevent reproduction of structure. External noise can restore ability of the group to reproduction of structure. At additive addition of stimulus with noise and due to adaptation, the absolute sensitivity of ANF goes down, but the on-set response is de- synchronized. As the fibers are adapted with external noise and for each its level there is a certain stimulus level when the structure of stimulus can be better reproduced in noise, than in silence.

The given statement has been checked up in psychoacoustic researchers on the auditory intensity discrimination (ID) of the short high-frequency stimulus presented in the simultaneous masking conditions. The effect of deterioration of ID of short stimulus in silence and the effect of facilitation of discrimination in noise has been found out enough time ago [1, 3, 6, 7] Effect observed for stimulus of average levels. As the authors of the works differently treated results of measurements and as connection of the facilitation effect with the detection thresholds of stimulus in noise specially did not have explanations it has been solved to repeat experiments of work [6] but under other conditions. It has been received [2] that in silence deterioration of ID was observed if the frequency band of stimuli has width equal of the auditory critical band (CB). Apparently, the reasons of deterioration lay in features of peripheral amplitude-temporal (not spectral) encoding of stimuli. The worst thresholds of ID are registered at a level of the stimulus making 20 dB above a audibility threshold. At additive addition of stimulus with noise the facilitation of ID was observed. The maximal value of facilitation is observed close to the detection thresholds of stimulus in noise. As well as in simulation researches, for each noise level there is the certain level of stimulus when of stimulus was better in noise, than in silence.

The effect of "deterioration - facilitation" of ID is observed for stimulus under forward masking conditions [5,8]. The stimuli had duration of 25 ms and frequency of 1000 Hz. Masker was the narrow-band noise having duration 100 ms, the delay between masker and stimulus was made 100 ms. It has been received, that in the range of average levels The discrimination was appreciable worse in noise than in silence. Treating results, authors [8] proceeded distinctions of the period of recovery process of the ANF excitability BCH with high and low spontaneous activity (SA). It was supposed, that in the range of average levels the stimuli was capable to cause reactions of saturation in the fibers having high SA and low detection thresholds, but could not cause reactions of the fibers having low SA and high detection thresholds. The ID was worsened, because the firing rate of ANF was not changed with changing of the intensity of stimulus.

The authors of other work [5] decided to check up this hypothesis carefully. In the same conditions of experiments they have combined stimuli with the notched noise, believing, that such addition will remove "off" frequency components and will even more worsen recognition. However instead of expected deterioration of ID they ware revealed the facilitation of ID similar those, received under simultaneous masking of stimulus by noise [6]. The authors [5] have assumed that the reasons of the received results it is necessary to search not on periphery, but in the central part of hearing.

With the purpose of revealing connection between peripheral encoding and ID of the short stimulus showed under forward masking, it has been solved to carry out special simulation and psychoacoustic experiments. The first part of researches was carried out on a model of ANF which description is given in work [2]. Here we shall only specify that the model will transform an input signal to sequence of spikes, taking into account the adaptation properties. The model reproduces known dependence of physiological properties of fibers on SA.

In accordance with a principle of volleys the fine amplitude-temporal encoding of the short high-frequency stimulus showed after the ending of the masker, carries out a short-term volley of ANF group. Such volley has two types of reactions: «stochastic» and «deterministic» ones. Occurrence of stochastic reactions is caused by SA. Occurrence of deterministic (or repeating) reactions is caused by frequency, level, duration of stimulus, and it also processes of the ANF recovery excitability. For a separate estimation of contributions of two types of reactions in reaction of group ANF, as well as earlier [2], the modified method of double pulses has been used. The double pulse's method is usually used for estimation of neuron' recovery processes (refractoriness and adaptation) [13]. The recovery process is indicated as the dependence of relative amplitudes of the second-pulse response or P2/P1 on inter-pulse intervals t, where P1 and P2 are sums of spikes, arisen by the first and second pulses. If pulses are enough short, the contributions of the reactions of two types (Ps2 and Pd2) in the reaction, evoked by the second pulse, can be estimated. They are calculated from P2-response, given that the second-pulse response occurs under condition of absence or occurrence of the first-pulse response, respectively. Note, P2=Ps2+Pd2, where Ps2 and Pd2 are the stochastic and deterministic component in P2-response.

In simulation experiments ability of ANF group to reproduce structure of single stimulus was estimated. It was accepted, that structure has been reproduced if the first and second half of short-term reaction, are identical. Proceeding from this, a time window in which there was a reaction (which we shall name the histogram) divided into two identical parts. In each of window it was estimated response P1 and P2. In experiment estimated dependences of responses P1, P2, and also P2/P1, Ps2/P1 and Pd2/P1 on a masker level. We expected the stimuli structure to be reproduced if response P2/P1 corresponds to unit.

Rules of structure reproduction showed simultaneously with noise [2] are kept for stimuli under forward masking (fig. 1). If stimuli close to the detection threshold that (1) absolute sensitivity the stimulus estimated on response P1 and P2 decreases; (2) response P2 are formed by stochastic way; (3) differential sensitivity of the structure reproduction grows, because relation P1/P2 comes to unit; (4) the more stimulus level the more masker level when the stimuli mask completely. Sharp distinctions of the structure reproduction appear at high stimulus levels in reaction of ANF group with low SA.

Responses P2 are absent at the stimulus level of 16 dB and at small noise level (fig.1). Growth of noise level (more than 7 dB) reduces responses P1 formed by deterministic way and increases responses P2 formed by stochastic way and responses P1 and P2 became even. After that the further growth of noise level simultaneously reduces both responses up to zero.

There are responses P2 formed by deterministic way at the stimulus level of 18 dB and at small noise levels. At first growth of noise level reduces up to zero the responses P2 formed by deterministic way. Then responses P1 reduces, responses P2 increases but forms by stochastic way. At noise level in 12 дБ arises a border on which responses P2 are not present. Thus, reproduction of structure is promoted by stochastic reactions of ANF group which appears close to detection thresholds. The deterministic responses, which appear at the high stimulus levels, hamper the structure reproduction.

Change of noise level is accompanied by mutual redistribution of contributions of in the total response P2. At the certain noise level there are the boundary levels sharing reactions of two types. The reproduction of stimulus amplitude-temporal structure was the worst of all on this boundary, i.e. it was appreciably worse in noise, than in silence. But the reproduction was the best close to the detection threshold, i.e. it was appreciably worse in silence, than in noise.

These conclusions have been checked up in special psychoacoustic researches. The technique of measurement is stated in work [2]. Here we shall give its brief description. The experiment was controlled

by an IBM PC-compatible computer. The stimuli were presented on both ears. Listeners were tested individually in a soundproof camera. Four normal-hearing listeners were used.

For definition of thresholds the «two down and one up» adaptive technique of two alternative, two interval forced choices has been used. The test sequence has two intervals shared by a pause of 700 ms. Duration of intervals were on 100 мс more then the masker duration. Eleven turn points were obtained. The threshold was taken as the mean level across last eight turn points. At least three valid runs were obtained. The thresholds were calculated as the mean across three listeners.

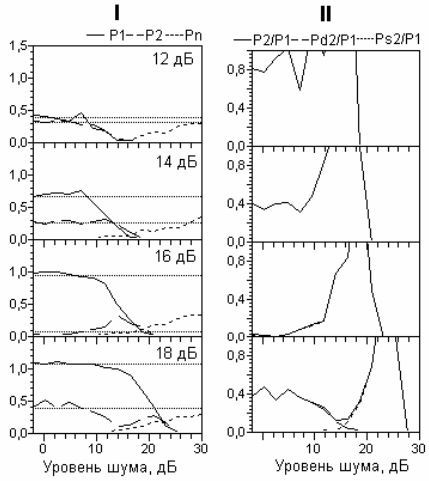

Fig. 1. Reactions of ANF-group caused by stimulus under forward masking. (I): Histograms, received on the stimulus with amplitude of 650. Parameters are P2/P1-response and noise level. On abscise: time in ms; on ordinate: sum of spikes, arisen in ANF-group containing 100 fibers. (II, III): Dependences of P1-, P2-, Pn- and P2/P1-, Ps2/P1-, Pd2/P1- responses on noise level. Parameters are the stimulus amplitudes. On abscise: noise level in dB (0 dB is accepted for noise detection threshold in fibers with high SA); on ordinate: amplitudes of responses. Dot lines correspond to P1- and P2- responses, received in silence. Pn- response is reaction of ANF-group on noise, estimated in a window of 2 ms not far from the end of noise.

Stimuli were Gaussian-windowed tones with carrier frequency of 4 kHz and a bandwidth of 1000 Hz. This bandwidth is equal to the critical band. Therefore a basis of ID is short volley of ANF encoding the amplitude–temporal, but not spectral structure of stimuli. The noise spectrum' maximum and its bandwidth were equal 4 kHz and 1000 Hz. The stimulus or noise levels of were estimated in dB of sensation level (SL).

Stimulus was showed under forward masking. The masker duration was 0,1 or 0,6 sec. The delay between the end of masker and the middle of stimulus was 3, 12 and 60 ms. The level of short stimulus in a discrimination task was 20 dB above a audibility threshold. At such level for the given group of listeners the ID thresholds in silence were the worst [2]. A masking levels and ID thresholds have been determined in experiments (fig. 2).

The value of facilitation depends on the delay, level and duration of noise. With the parameters' increasing the ID facilitation grows. If the delays are 2 and 12 ms, the value might be equal 2 or 6 dB at the noise duration of 0,1 or 0,6 s (fig. 2). Increasing of the delay up to 60 ms conduce not only to increasing in the value up to 7 or 14 dB at noise duration of 0,1 s or 0,6 s, but also to broadening in the range of noise levels where this ID facilitation can be detected (fig. 2, bottom). Obviously a slight slope of the dependence of masking level on noise level is assisted these increasing and broadening (fig. 2, top).

The following two facts are especially important for us because they have been predicted by simulation experiments. The first, the more the delay the more not only the value of facilitation, but also the more the area of the noise levels, in which facilitation is observed. Growth of the facilitation value and broadening the range of masker levels at which the simplification is present, obviously are promoted by a slight slope of the dependence of masking level on noise level. The second, the range of ID facilitation can

precede the range of ID deterioration. The maximal ID deterioration achieves 3-5 дБ and appears at the masking level of 5 dB approximately. Occurrence of deterioration is obviously connected with delay, duration and level of masker. At delay 60 and 12 ms ID deterioration causes the masker with duration 0,1 ms. Masker with high level and long duration does not cause ID deterioration.

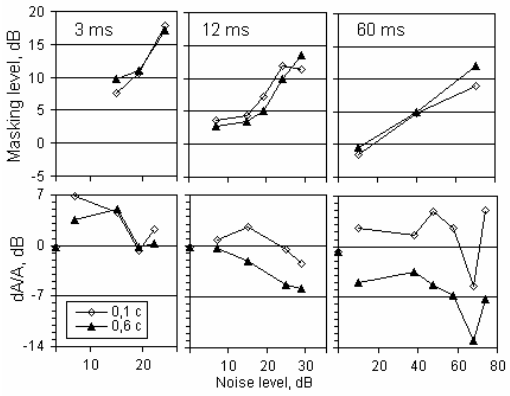

Fig. 2. Dependences of the masking levels (top) and IDT (bottom) on the noise level for the stimulus under forward masking. Parameters are the delays between stimulus and noise in ms and the noise durations in s. On abscise: noise level in dB. On ordinate: the masking level in dB; and IDT in dB, where dA is the minimal increment of intensity found out by the listener.

The results correspond to the known data [3]. It has been shown that under simultaneous masking ID facilitation appears for the stimulus masking level of 10 dB and at the level of masker of 40 dB. However for the same of the masking level and at the level of masker of 15 dB ID deterioration appears. ID deterioration was also caused by noise having duration of 100 ms and level of 90 dB under forward masking [8].

Our measurements show, that features of ID (fig. 2) are kept the same under forward and simultaneous masking [2]. It was showed that ID of short stimulus with bandwidth limited one critical band is better close to the detection threshold for stimulus presented in silence or in noise [2] and (fig. 2). ID can be worsening by "average" noise, but it can be improved by "strong" noise (fig. 2).

Under forward masking, as well as it is predicted by simulation researches, increasing in a delay between stimulus and noise increases the value of ID facilitation and the range of noise levels in which the effect of ID facilitation (fig. 2) is observed. The basic results of simulation and psycho acoustical researches were the same. Therefore it is possible to assume that influence of peripheral amplitude-temporal encoding of short stimulus on auditory ID exists. Work supported by the RFBR (grant № 06-04-48456).

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