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# USE OF SIMULTANEOUS RECORDING OF AUDITORY CORTICAL-EVOKED POTENTIALS AND COCHLEAR MICROPHONE POTENTIALS TO STUDY THE MECHANISM OF AUDITORY ADAPTATION

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Intensive acoustic stimulation is known to reduce auditory sensitivity, i.e., to raise the thresholds of audibility. This rise of thresholds may persist for some time after the end of above-threshold acoustic stimulation. The amount of the rise in thresholds and the time required to restore their initial level are determined under normal conditions by the strength and duration of the acoustic stimulation. This fact is described in the literature under various names: "direct and reversed adaptation," "the fatiguing effect of noise," "the time shift of the auditory thresholds." However, ideas on the mechanism of this phenomenon are highly contradictory in character. Some workers ascribe the leading role to the central divisions of the auditory system [1, 6, 14], others to its peripheral formations and, in particular, the spiral organ [8, 11, 13] and, finally, others attach importance to the nonspecific systems of the brain stem [5, 7].

To shed light on this problem experiments were required with simultaneous recording of electrical auditory responses from central and peripheral structures of the auditory system, and the investigation described below was carried out for this purpose.

## EXPERIMENTAL METHOD

Auditory evoked potentials (AEP) were recorded from the cortex and microphone potentials (MP) from the cochlea. The technique of deriving and recording the AEP was fully described by the writers previously [3, 4]. The animals were anesthetised with chloralose and pentobarbital. Cortical AEP was recorded in one channel of the recording system, MP from the cochlea were recorded synchronously in the other channel. MP was derived from the fenestra rotunda by means of a nichrome electrode. Approach to the cochlea was obtained through the bulla ossea. The electrode was fixed with acrylic glue.

Both potentials were reproduced by tonal stimulation with definite parameters. The duration of the tonal stimulus was 20 msec, the rise time 2.5 msec, and the filling frequency 0.5, 1.0, 4.0, and 8.0 kHz. Stimulating volleys were applied with a frequency of once per second. Stimuli were generated by an AUG-69 audiometer with an attachment enabling the assigned stimulus parameters to be formed. White noise was used as the above-threshold strong stimulus. The intensity of the noise was 90 dB above the $2 \times 10^{-5}$ P level, and exposure lasted 10 min. The noise was generated by means of a second AUG-64 audiometer. The sound emitters

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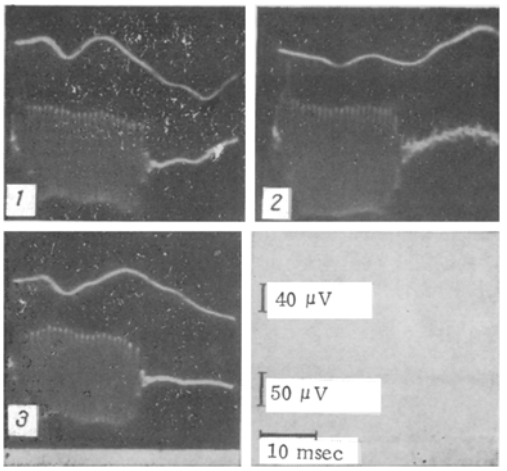


Fig. 1. Effect of intensive white noise on AEP of a rabbit. 1) Before, 2) during action of white noise with intensity of 90 dB; 3) 1 min after exposure to white noise of the same intensity for 10 min. Top beam shows cortical AEP, bottom beam shows cochlear MP.

were TDH-39 electrodynamic telephones, connected to the animal's external auditory meatus by means of a three-way tube, so that both tonal volleys and continuous white noise could be applied to the same ear in any order and in any combination. The telephones were calibrated directly in the auditory meatus. Potentials were recorded frequently before, during and after exposure to white noise for 10 min.

## EXPERIMENTAL RESULTS

Thresholds of reproduction of AEP under the conditions described were 20–25 dB; the thresholds of reproduction of MP at low frequencies approximately coincided with those of reproduction of AEP, but at high frequencies (4–8 kHz) they exceeded them by 30–40 dB.

During exposure to white noise the AEP to tonal volleys with an intensity of 90 dB were completely suppressed, whereas the MP were hardly changed (Fig. 1). Immediately after the end of exposure to white noise, AEP could be recorded again, but the thresholds of their reproduction were much higher than initially; on average for all experiments thresholds of reproduction of AEP were increased by $17.0 \pm 1.0$ dB. No difference could be found in the degree of elevation of the thresholds when AEP were recorded after exposure to white noise. The thresholds of reproduction of AEP later gradually diminished and returned to their initial value after a short time. The mean time for restoration of the initial thresholds was $214.0 \pm 15.0$ sec, irrespective of the frequency of the tonal volleys to which the AEP were recorded. Throughout this time the thresholds of reproduction of cochlear MP showed no significant change.

The fact that AEP changed under the influence of noise in the absence of any shifts of MP, described above, suggests that the leading role in the mechanism of the decrease in auditory sensitivity during exposure to loud noise belongs to the central, and not peripheral, structures of the auditory system.

This hypothesis was confirmed during a study of the action of neurotropic drugs on auditory fatigue. The drugs used were those which, as the writer showed previously [4], increase the amplitude of AEP and affect their latent period, namely: galanthamine, GABA, and nanophyne. The times of determination of adaptive shifts under the influence of these drugs were established on the basis of the results of that same investigation [4] and corresponded to the time of maximal change in amplitude of the AEP after administration of the corresponding drugs.

Intravenous injection of galanthamine in a dose of 2.5 mg/kg in the period from 15 to 45 min before exposure to white noise considerably reduced the effect of depression of auditory sensitivity by noise compared with that in intact animals: the thresholds of reproduction of AEP were raised under these circumstances by only 9 dB and were restored after 101 sec (the difference from the corresponding indices before injection of the drug is statistically significant, Table 1).

TABLE 1. Effect of Drugs on Adaptive Processes in Auditory System of Rabbits

| Index | Before administration of drugs | After administration of galanthamine | After administration of GABA | After administration of nanophyne |
|---|---|---|---|---|
| Elevation of thresholds under the influence of noise, dB | 17,0±1,0 | 9,0±2,0 | 12,1±3,0 | 7,0±2,0 |
| P | | <0,02 | >0,1 | <0,02 |
| Time for restoration of thresholds, sec | 214,0±15,0 | 101,0±30,0 | 210,0±5,0 | 88,0±18,0 |
| P | | <0,05 | >0,2 | <0,01 |

This type of effect can evidently be explained by the anticholinesterase properties of galanthamine, facilitating the conduction of impulses through synapses in the CNS.

By contrast, GABA had no effect on the fatiguing action of prolonged loud noise. With an exposure of 10 min to white noise with an intensity of 90 dB 15-45 min after intravenous injection of GABA in a dose of 250 mg/kg body weight the degree of elevation of the thresholds of reproduction of AEP and the time of recovery of their initial level did not differ significantly from the corresponding values before injection of the drug (Table 1).

One possible explanation of this absence of effect on the resistance of the auditory system to loud noise could be that GABA is an inhibitory mediator of central synapses [9].

In the light of data in the literature [10, 12, 15] confirming the role of sympathetic influences in the regulation of activity of the auditory system, the results of an investigation of the action of the peripheral ganglion blocker nanophyne on the adaptive properties of the organ of hearing were felt to be interesting.

In experiments in which nanophyne was injected intravenously into the animals in a dose of 12 mg/kg 15-45 min before exposure to noise, a marked increase in resistance of the auditory system was observed. Thresholds of reproduction of AEP in this case were raised on average by only 7 dB and were restored after 88 sec (the difference from the corresponding indices before injection of the drug is statistically significant (Table 1). This can be explained on the grounds that nanophyne, like other ganglion blockers, blocks nicotinic cholinergic systems and increases the reactivity of adrenergic and muscarinic cholinergic systems, potentiating the action of adrenalin and acetylcholine [2].

These investigations are thus evidence that, first, the process of auditory adaptation is reflected in the cortical-evoked potentials. It can be assumed that the mechanism of auditory adaptation is due to processes taking place in synapses of the central divisions of the auditory system and that it is controlled by the sympathetic nervous system.

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