ABSTRACT:

Auditory cortex (AC) is the ultimate target of afferent auditory pathways and plays a crucial role in the perception and localization of complex sounds. In the thesis were investigated and discussed three aspects of the AC function: i) diversity of the intrinsic passive and active electrical properties of core and belt AC neurons, ii) the modulatory function of the descending connections from the auditory cortex to the inferior colluculus and iii) the effect of a complex acoustical environment applied during the critical period on the responsiveness of auditory cortex neurons in rats.

Within the AC can be distinguished two fundamental areas: centrally located core area and peripheral belt area. Recordings of sound-evoked AC activity revealed striking differences between response patterns of neurons from the core and belt areas. Most of core neurons displayed short latency, phasic responses, unlike the prevalence oflonger latency tonic responses in the belt area. It has been hypothesized that incoming signals could be processed differently by neurons in these areas. In thethesis we have investigated the intrinsic electrical properties of layer V pyramidal neurons by patch-clamp recording in acute rat AC slices. Results showed that the pyramidal neurons from the core AC are more excitable at rest with increased time membrane constants andinput resistances and generated action potentials with shorter latencies and lower rheobasescompared to neurons from the beltregion. The different excitability resulted from an elevated constitutive shunting conductance activated in belt neurons at the resting membrane potential. The hyperpolarization activated/cyclic nucleotide-gated cation (HCN) channels were identified as the mediator for this elevated conductance in the belt pyramidal neurons. Analysis of voltage-dependence and gating kinetics of HCN-mediated currents (Ih), single-cell RT-qPCR and immunohistochemistry revealed the HCN1and HCN2 as the major subtypes expressed inboth auditory areas. Experimental blockade of Ih confirmed its important role in the regulation of spiking ability of pyramidal neurons in the belt regions.

The existence of massive projections descending from the auditory cortex (AC) to the inferior colliculus (IC) is well documented, yet their function is not fully understood. The modulatory effect of corticofugal projection on the responses of neurons in the rat IC was examinedusing a reversiblecortical inactivation, achieved by cooling of the AC.The frequency tuning and thresholds of the IC neurons did not show any significant changes during the cooling period.But at the same time, cooling of the AC produced an increase in spontaneous activity as well as inmagnitude of the sound-evoked response in 47% of the IC neurons. The final segments of the sustainedresponses and the off responses were more affected than the onset segments.

Changes in the neuronal activity were observed in the dorsal cortex as well as in the central nucleus of the IC. Inactivationof the AC resulted also in a suppression of the post-excitatory inhibition and neuronal adaptation, which was reflected in a pronounced enhancement of synchronized responses to a series of fast repeatedclicks. The response parameters recovered, to the pre-cooling levels within 1 h after the coolingcessation. The results demonstrate that AC cooling inactivates excitatory corticofugal pathwaysand results in a less activated intrinsic inhibitory network in the IC.

Acoustical environment plays an important role during the maturation of the auditory system. It has been shown that the sensory inputs to the developing centresinfluence the development of the structure of projections, neuronal responsiveness, excitatory-inhibitory balance, or tonotopical arrangement, throughout the auditory pathway. The current work provides evidence that rats reared in a complex acoustic environment (spectrally and temporally modulated sound reinforced by an active behavioral paradigm with a positive feedback) exhibit permanently improved response characteristics of the AC neurons. In particular, the enriched animals had lower excitatory thresholds, sharper frequency selectivity, and a lower proportion of non-monotonic rate-intensity functions. In addition to this, the enrichment changed the AC responsiveness to frequency-modulated and also amplitude-modulated stimuli. For a repetitive stimulus, the neurons exhibited a lower spike count variance, indicating a more stable rate coding. At the level of individual spikes, the discharge patterns showed a higher degree of similarity across stimulus repetitions. Furthermore, the neurons followed more precisely the temporal course of the stimulus, as manifested by improved phase-locking to temporally modulated sounds. These acoustical enrichment- induced changes developed during system maturation were permanent and detectable in adulthood. The findings indicate that an acoustically enriched environment during the critical period of postnatal development influences basic properties of neuronal receptive fields in the auditory cortex, which may have implications for the ability to detect and discriminate sounds and also affects the stochasticity, reproducibility, and fine structure of neuronal spiking patterns.

Results of the thesis contributing to knowledge about neuronal implication of signal processing within the AC circuits, cortical control of the subcortical processing of acoustical stimuli and a role of acoustical stimulation for formation of the auditory system during maturation.

Keywords: auditory cortex; corticofugal modulation; neurons; acoustically enriched environment; plasticity; critical period.