

# SOUND LOCALIZATION AND THE UNDERLYING NEURAL CODE

*Petr Marsalek*

*Jiri Kofranek*

Charles University Prague, First Medical Faculty, Department of pathological physiology,

U nemocnice 5, Praha 2, CZ-128 53, Czech Republic

<http://patf.lf1.cuni.cz>

[mailto: marsalek@karlin.mff.cuni.cz](mailto:marsalek@karlin.mff.cuni.cz) -

<http://www.karlin.mff.cuni.cz/~marsalek>

[mailto: kofranek@mbox.cesnet.cz](mailto:kofranek@mbox.cesnet.cz) - <http://physiome.cz>

## ABSTRACT

Sound localization pathway separates from the rest of auditory pathway at an early processing stage, after cochlear nuclei. At the top of the hierarchy of all sensory pathways, in cerebral cortex, the information about the sound direction is integrated together with other sound qualities to yield an unified percept. The succession of names of anatomical structures of the pathway is: from cochlear nuclei (CN), through medial and lateral superior olive (MSO and LSO), inferior coliculus (IC), medial geniculate nucleus (MGN) and finally primary (A1) and some auxiliary (CM, caudo-medial area, in macaque) auditory cortical areas.

At the Neural Coding Workshop in the 1999, we have shown nonlinear aspects of sound direction processing at one lower stage, represented by the MSO in mammals, [3]. We have also shown, why is the mechanism used in MSO limited to low frequency band, [4]. In the current work we are interested in a question how different sound modalities, loudness, main frequency, sound direction, and sound duration are encoded by spike trains along the pathway and what is the resulting representation of these qualities at the auditory cortex.

The traditional view is that in the MSO, azimuth is detected along the (anatomically distinct) delay line and encoded as spikes in a labeled line code. In the LSO, the balance of firing rates from the two sides detects and also encodes the azimuth. Experimental observation shows that only few components of the stimulus are discarded during relaying of spikes in these lower relays of the pathway. These components are compressed by nonlinear gains and retained instead. In the MSO, the compressed sound level is also signalled. The sound level is encoded by the spike count at the adjacent neurons, this is called neuronal recruitment. The sound frequency is confined to tonotopically tuned (labeled) lines. Finally the spike timing is preserved, because it is used in azimuth computations. In the LSO, the spike timing is propagated through, as demonstrated in newer experimental results on delays in the LSO, [2]. Also in the LSO, the tonotopic frequency organization is preserved, and the sound level is used in azimuth computation.

The main difference between sub-cortical and cortical neurons in auditory pathway is that the former do not adapt and the latter adapt because of adaptive potassium membrane currents, [6]. Inhibitory suppression is also involved in their response adaptation. The spiking response in cortex is therefore brief. This in extreme will result in producing just one spike in response to the relevant stimulus. In the two sound localization cortical areas (A1 and CM), transient responses are most common, [5]. In other cortical areas, similar stimulus encodings were proposed, [7]. The sound modalities mentioned here, encoded in firing frequencies or on labeled lines in sub-cortical stages are therefore re-coded into isolated spikes.

This is consistent with the hypothesis that relevant signals in neocortex are transmitted by packets of spikes traveling from one area to another and that these packets enable interfacing among cortical areas, [1].

Using Matlab, we model input and output spike trains in successive nuclei of the sound localization pathway (CN, MSO, LSO, IC, MGN and auditory cortex). Encoding of sound modalities using encoding schemes outlined above is shown in examples of MSO, LSO and auditory cortex. This is compared with the proposed encoding in the cortex.

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