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Synaptic contact number and transmitter exocytosis are maximal in mouse inner hair cells corresponding to frequencies of best hearing.

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The sensitivity of sound perception is highly dependent on the frequency - each detected at a specific tonotopic location in the cochlea. Here, we investigated whether the morphological and physiological properties of the afferent hair cell synapses could contribute to this phenomenon. We found that the number of synaptic contacts per inner hair cell had a maximum in the cochlear region that transmits sounds with highest sensitivity (10-24 kHz). Confocal microscopy of the organ of Corti following immunostaining for RIBEYE, a major component of the synaptic ribbon and for AMPA-receptor subunits GluR2 and 3 was performed to estimate the number of afferent synaptic contacts as colocalized spots of pre- and postsynaptic immunofluroescence.

We then investigated the presynaptic function of inner hair cells at different positions along the apical turn of the cochlea by perforated patch-clamp recordings. Probing exocytosis by measurements of cell capacitance increments after brief depolarizations, we found that hair cells located ~300 µm from the apex released 44% less transmitter than cells located at ~1400 µm from the apex. This functional finding corresponded to a 31% difference in the number of morphologically identified afferent synapses betwen these locations. Interestingly, size, charge and kinetics of the calcium current did not vary with the tonotopic position of the hair cells.

As the IHC Ca2+ influx may not only depend on the synapse number but also on the active zone size we asked whether the size of presynaptic ribbons may vary tonotopically. The Ribbon size distributions at the two tonotopic positions of ~180 and ~1060 µm, as estimated by 4Pi high-resolution optical microscopy, were indistinguishable from each other.

In conclusion, the cochlea may use a maximum of neural information channels per hair cells in the range of best hearing. The comparable Ca2+ current despite varying IHC release area might indicate a significant number of extrasynaptic Ca2+ channels.