Supplementary Materials

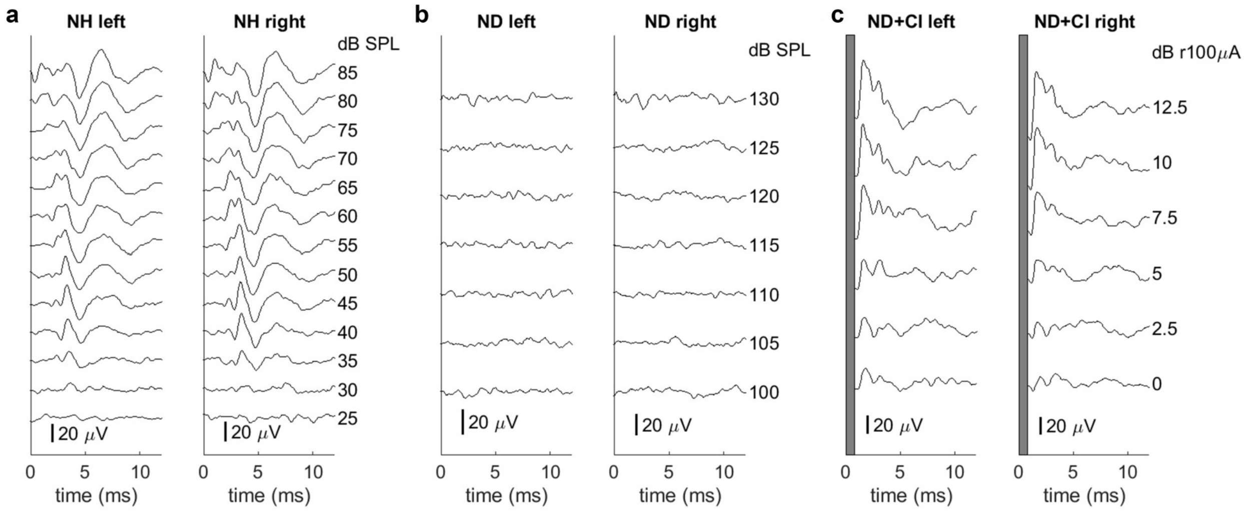

Figure S1: Brainstem recordings to verify normal hearing or loss of hearing function as well as the symmetrical placement of CIs. **a** Auditory brainstem responses of an acoustically stimulated normal hearing (NH) rat. ABRs are symmetrical for both ears and show clear differentiation. **b** ABRs of a neonatally deafened (ND) rat. No hearing thresholds were detectable up to 130 dB SPL. **c** Electrically evoked ABRs under CI stimulation of a deafened rat. Each subpanel includes measurements for the left and the right ear, respectively, under acoustic (**a-b**) or electric stimulation (**c**).

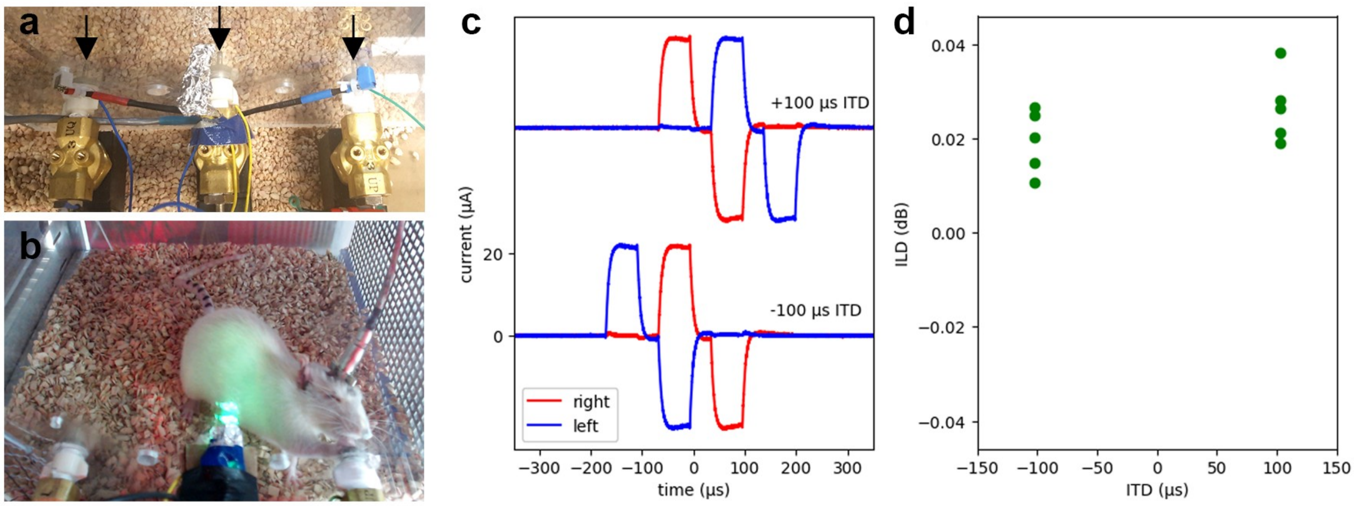

Figure S2: Binaural electrical intracochlear stimulation of CI rats. **a** Close-up of the training setup for CI rats. The central “start” and lateral “response” spouts deliver the water reward and are indicated by arrows. **b** CI rat during a testing session, making a response to the left by making contact with the left reward spout. **c** Calibration measurements were performed by connecting the stimulator cable to 10 kOhm resistors instead of the in-vivo electrodes and recording voltages using a Tektronix MSO 4034B oscilloscope with 350 MHz and 2.5 GS/s. Recordings of stimulus pulses are shown with 100 μs ITD leading in the right ear (top) or the left ear (bottom) respectively. Pulses delivered to the right ear are shown in red, those delivered in the left ear in blue. The stimulator was programmed to produce biphasic rectangular stimulus pulses with a 20 μA amlitude (y-axis) and a 23 μs inter-pulse interval. **d** Measured calibration pulses such as those shown in (**c**) were used to verify that electric ILDs were negligible and did not vary systematically with ITD. ILDs were computed as the difference in root mean square (RMS) power of the signals in (**d**). Data from five presentations of ITDs of + or – 100 μs are shown by the green dots. These residual ILDs produced by device tolerances in our system are not only an order of magnitude smaller than the ILD thresholds for human CI subjects reported in the literature (~0.1 dB [73]), they also do not covary with ITD. We can therefore be certain that sensitivity to ILDs can not account for our behavior data.

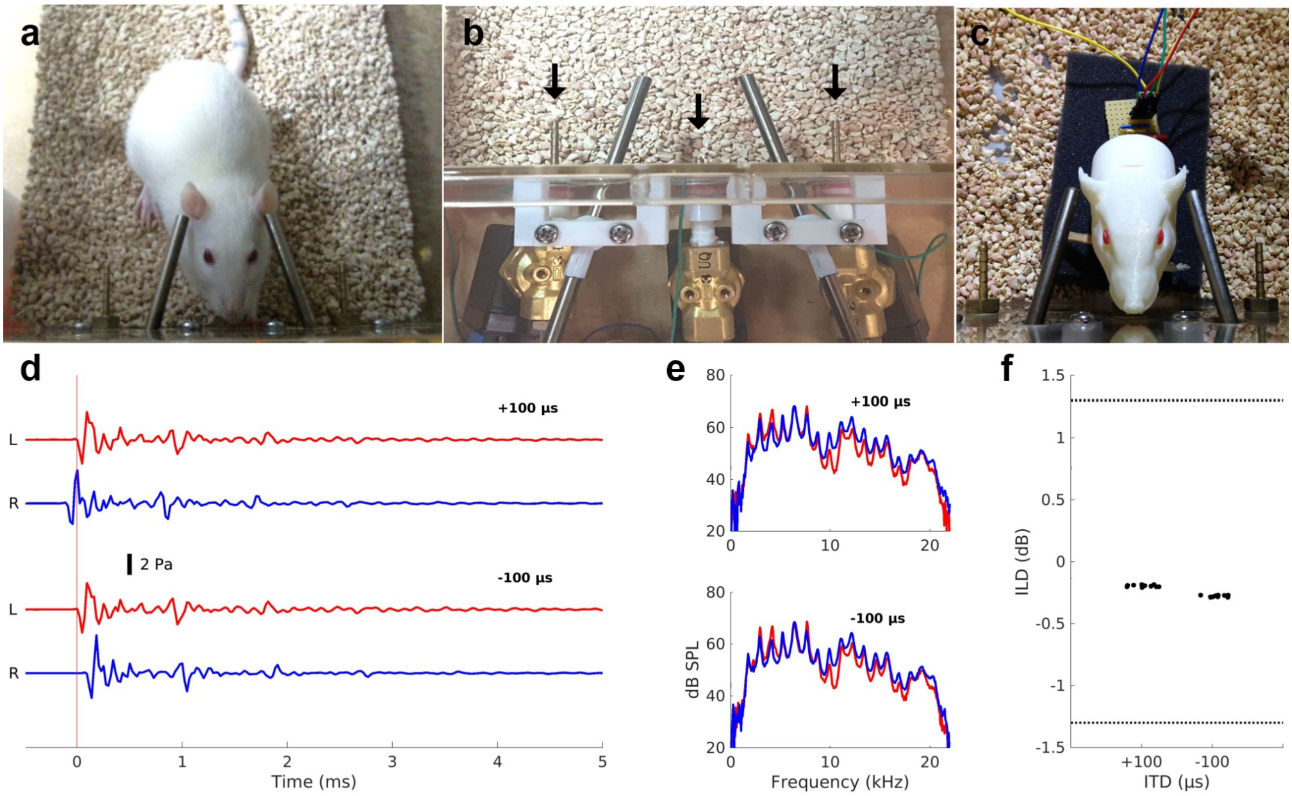

Figure S3: Binaural psychoacoustics near-field setup for NH rats. **a** NH rat during a testing session, initiating a trial by making contact with the central "start" spout. Steel tube phones are positioned close to each ear. **b** Close-up of the assembly. The central "start" and lateral "response" spouts deliver the water reward and are indicated by arrows. Also visible are the custom ball joints for adjusting the tube phone positions. **c** 3D printed "rat kemar head" with miniature microphones in each ear canal, used for validating the setup. **d** Validation data for acoustic click stimuli as recorded from the microphones inside each ear canal of the 3D printed "rat kemar head" (L: left ear, R: right ear) in response to the +/- 100 µs ITD conditions (top and bottom pair of traces, respectively). **e** Frequency spectra of the sound waveforms recorded by the microphones in each ear for the +100 µs (top) and -100 µs (bottom) conditions. **f** Acoustic ILDs (y-axes) measured through the kemar microphones for the +/- 100 µs ITD conditions. ILDs were computed as the difference in root mean square (RMS) power of the signals in panel (**d**). Data were recorded from 10 presentations of each ITD stimulus, and each dot represents one trial (a random amount of scatter along the x-axis was added for ease of visualization). Note that the residual ILDs are much smaller than the reported behavioral thresholds for ferrets (~ 1.3 dB, dotted line, [32]) or rats (~3 dB [34]). We can therefore be certain that sensitivity to ILDs can not account for our behavior data.