Onset Weighting of Temporal Spatial Cues with Cochlear Implant Stimulation in Early Onset Deafness

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Background

- Using binaural temporal cues is a major challenge for cochlear implant (CI) users, particularly with early and prolonged auditory deprivation [1].
- However, our own studies show that, even in the absence of auditory input during infancy, rats can become highly proficient at temporal spatial perception using interaural time differences (ITDs) if given precise ITD cues right after implantation[2].
- **Binaural adaptation**' is the reduced usefulness of interaural info after signal onset with increasing click rate. This can be reset with the use of **temporal gaps** [3]. Additionally the benefits of increasing amplitude modulation depths on speech cue extraction has been demonstrated in CI users. Both suggest the need of strong **onset spatial cues**.
- Previous studies have shown long term reweighting of spatial cues following altered developmental hearing experience [4].
- Here we investigated the **temporal weighting** of ITD cues in both **acoustic** and **CI stimulated rats**.

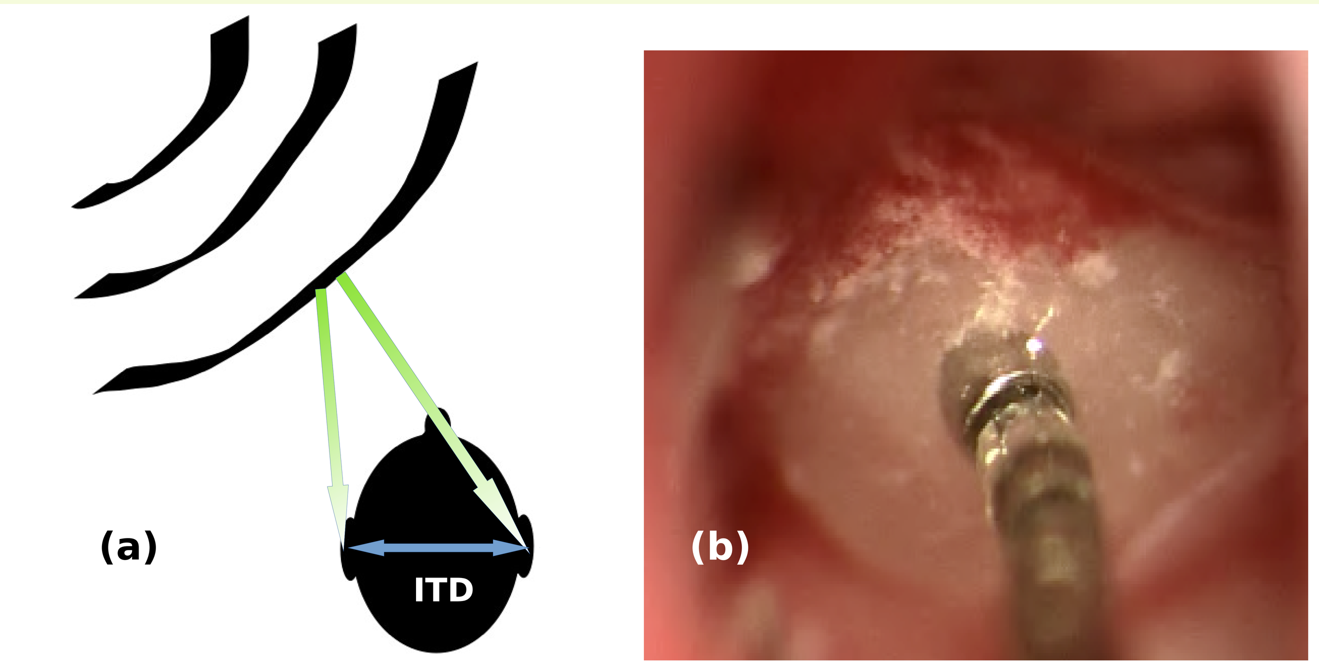

Figure 1: (a) Schematic representation of ITD stimuli. (b) CI inserted into the middle turn of the rat cochlea through a cochleostomy.

Method I

Subjects

- 8 neonatally deafened (ND) and 4 normal hearing experienced (NH) adult female Wistar rats.

Neonatal deafening (n=8)

- intraperitoneal kanamycin (400mg/kg) from day p9 to p20 [7].
- Antibiotic ototoxicity results in hearing loss ≥95dB SPL confirmed with auditory brainstem responses.

CI surgery

- Under general anaesthesia in early adulthood.
- Bilateral CIs (BiCIs) inserted into the middle turn through a cochleostomy window in the 8-16kHz frequency range.

Behavioural Experiment

- **2-alternative forced choice (2AFC)** with water reward.
- Acoustic stimuli delivered as click trains through near field ear bars.
- CI stimuli delivered directly to cochlea as biphasic, bilateral electrical pulses.

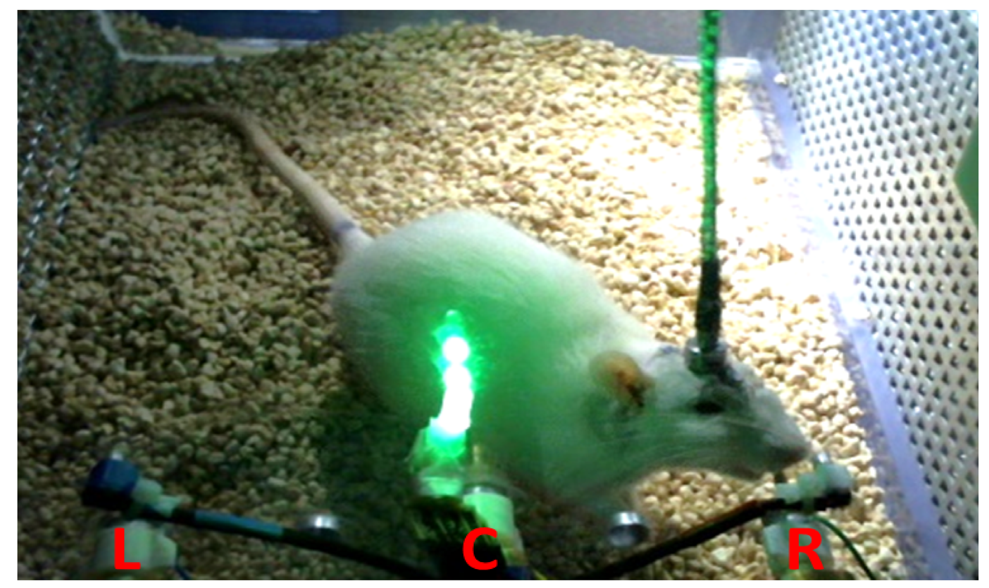

Figure 2: Setup for training bilateral CI-implanted rats on 2AFC binaural discrimination task by presenting ITD pulse trains directly to CIs. Three solenoid valves (L,C ,R) with capicitance detector. Rat licks a computer interface and triggers release of water when response is correct. Incorrect responses results in a timeout.

Method II

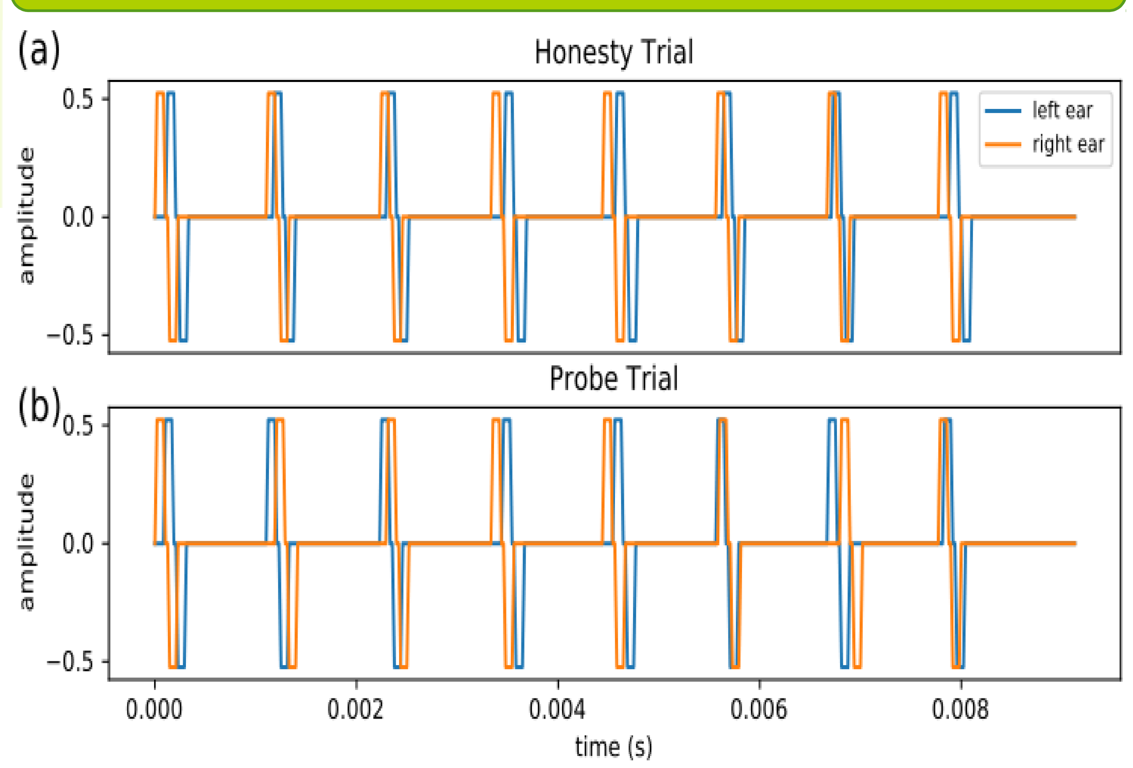

Figure 3: Examples of two trial types for electric biphasic pulse trains at 900 Hz delivered to CIs. (a) Honesty trial with only right leading ITDs with random jitter per pulse. (b) Probe trial with jitter jumping randomly between left and right leading ITDs. Amplitudes are relative to 100 μA at 0dB.

- All ITDs within rats' physiological range of +/-120 μs [8]. Negative denotes left ear leading.
- Training session randomly interleave probe and honesty trials (figure 3), each 8 pulses/clicks long, presented at 50, 300 or 900 pulses/s.
- In **Probe Trials,** the ITDs for each click are drawn independently and uniformly from the set {-120, -80, -40, … -120} μs.
- In **Honesty Trials,** the ITDs for each pulse were drawn from **either** {-120, -80, -40} or {+40, +80, +120} μs. In honesty trials all ITDs point to the same side. They outnumbered probe trials 4:1, and animals had to respond correctly. In probe trials the animal rewarded on either side.
- **Temporal Weighting Functions (TWFs)** were calculated using multiple linear regression of probe trials only, regressing the animal's probability of choosing "right" against each click's ITD [5].

Conclusion

- **Normal hearing TWFs** for all frequencies **and CI TWFs** on average are **comparable with those observed in humans** [5] and show strong onset weighting, as expected given the precedence effect.
- **Neonatally deafened**, electrically stimulated animals, showed much **weaker onset weighting** as well as significant weighting on duration cue pulses particularly for 900Hz.
- **CI animals** also showed **higher weighting variability** inter and intra **individually**, particularly with increasing pulse rate. 3 of the 8 ND animals were unable to perform the task at all despite being able to perform accurately with constant ITDs at the same pulse rate.
- **CI rats** also had **more variability in Honesty Trial** performance with increasing pulse rate as well as more sessions less than 75%.

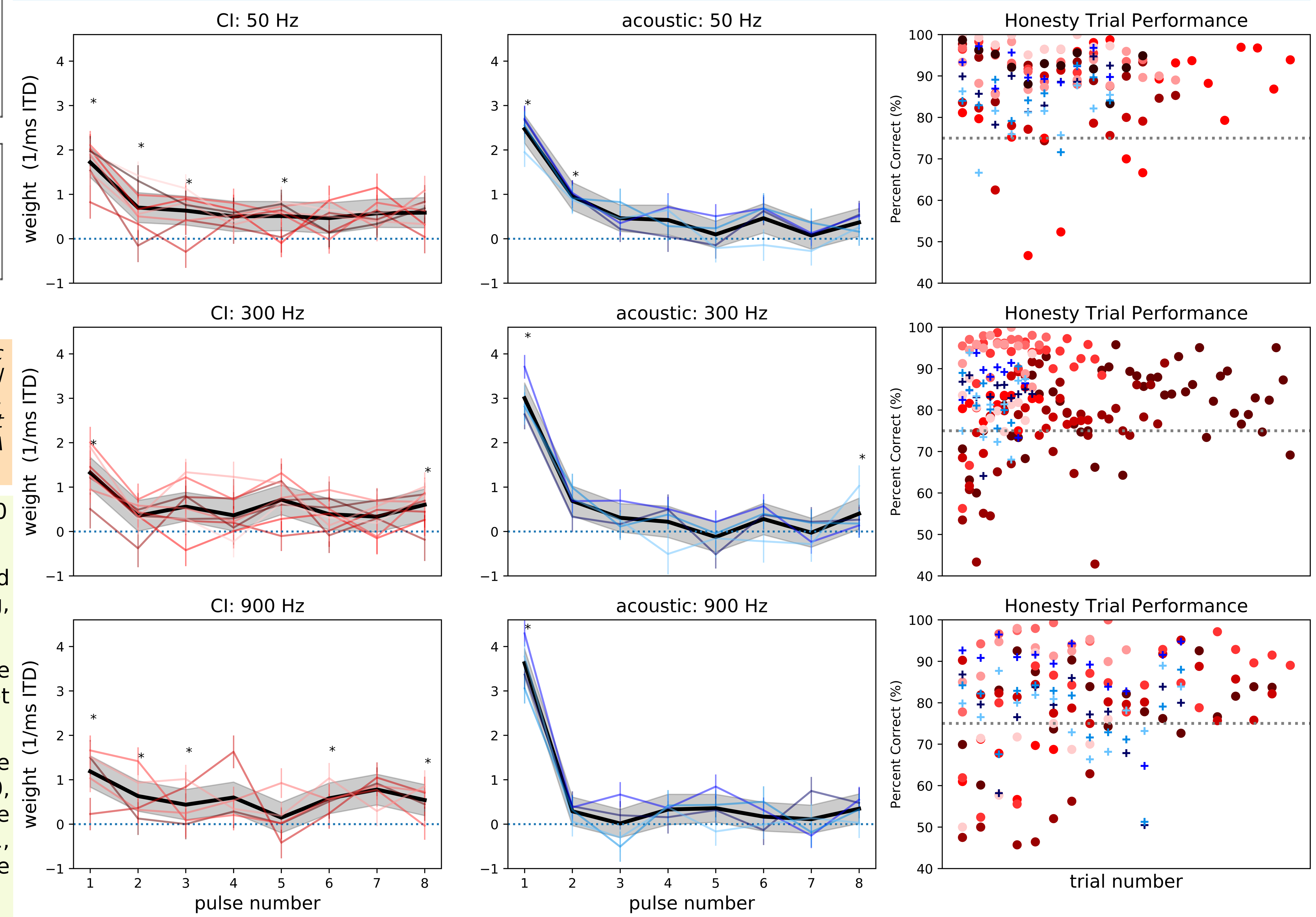

Figure 4: TWFs and performance levels for Honesty Trials. Top, middle and bottom row show results for 50, 300 and 900 Hz respectively. Left (CI) and middle (NH) columns show temporal weighting for each of the eight pulses, calculated as a linear regression weight in 1/ms ITD. Each animal is shown in a different colour. Black lines are pooled results from all animals. Error bars and shading show SEM. The right column shows the performance for Honesty trials in each session. Only sessions >75% correct (dashed line) were included in the TWF analysis. Each individual animal is a different marker shape with CI animals in red and NH animals in blue.

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