Temporal weighting functions for binaural cues in rats

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Introduction

The "temporal weighting function" (TWF) quantifies how strongly lateralization judgments in spatial hearing are influenced by the onset, middle, or offset of a sound respectively. They are usually measured in psychoacoustic experiments using binaural click trains, in which individual clicks differ in their binaural cue values. Human listeners tend to show a strong "onset bias" in such studies (Brown and Stecker, 2010; Stecker and Hafter, 2002; Stecker, 2014). While the shape of the TWF is likely to be similar in other mammals, to the best of our knowledge, this has not previously been shown. To measure the TWF for rats, we performed psychoacoustic experiment using click train stimuli with jittered interaural time differences (ITDs) and interaural level differences (ILDs).

Methods and materials

Animals: Four 8-week old female Wistar rats.

Task: Two-alternative forced choice (2AFC) near-field lateralization task.

Stimuli: Click trains with 8 clicks in a train.

Click rates: For ITD: 20, 50, 300 and 900 Hz. For ILD: 300, 900 and 1800 Hz.

TWFs calculation: Computed TWFs by calculating a multiple regression of the ITD or ILD values against the animals' "left" or "right" responses for the probe trials only.

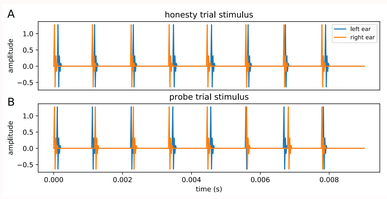

Fig. 1 ITD Stimuli example. ***A***: honesty trial stimulus at 900 Hz with 0.04 ms jitter and +0.08 ms offset (+: right ear leading, –: left ear leading). The time differences between each click pair was in the range of +0.04 ms to +0.12 ms, which means every click pair leading to the right ear. There is no ambiguity and the rat will only be rewarded for responding "right". ***B***: probe trial stimulus with 0.12 ms jitter and 0 ms offset. The time differences between each click pair was randomly assigned in the range of – 0.12 ms to + 0.12 ms. There is no objective "correct" response to a probe trial, therefore, rats could get rewards licking either side water spout. In the experiments, "honesty trials" (80% of trials), and "probe trials" (20%) were randomly interleaved.

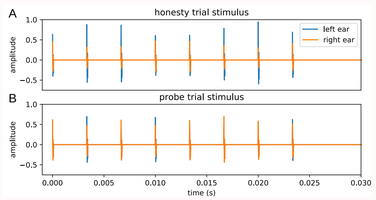

Fig. 2 ILD Stimuli example. ***A***: honesty trial stimulus at 300 Hz with 4 dB jitter and - 6 dB offset (+: right ear leading, –: left ear leading). The sound pleasure level (dB) differences between each click pair was in the range of - 2 dB to - 10 dB, which means every click pair leading to the left ear. There is no ambiguity and the rat will only be rewarded for responding "left". ***B***: probe trial stimulus with 6 dB jitter and 0 dB offset. The time differences between each click pair was randomly assigned in the range of – 6 dB to + 6 dB. There is no objective "correct" response to a probe trial, therefore, rats could get rewards licking either side water spout. In the experiments, "honesty trials" (80% of trials), and "probe trials" (20%) were randomly interleaved.

Results

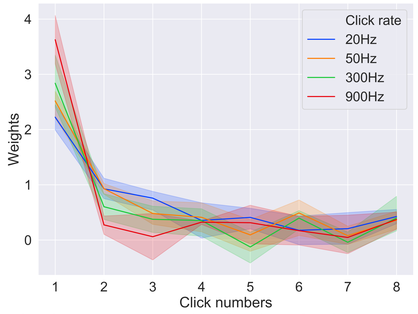

Fig. 3 Temporal weighting functions for interaural time differences at different click rates in rats. The weight of first click was significantly higher than that of the rest clicks. The onset weighting was highest at 900 Hz and decreased according to the decreasing click rates. The weight of the 8th (last) click was raised comparing to the 7th Click. Confidence interval = 95%.

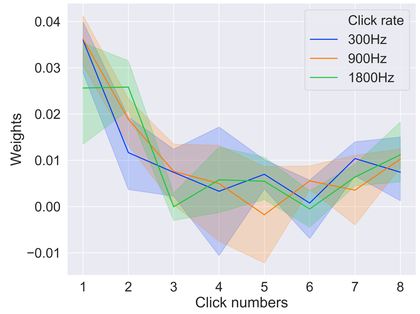

Fig. 4 Temporal weighting functions for interaural level differences at different click rates in rats. At 300 Hz and 900 Hz, the first click was equally weighted significantly high, while at 1800 Hz, the first and second clicks were weighted similarly high. Confidence interval = 95%.

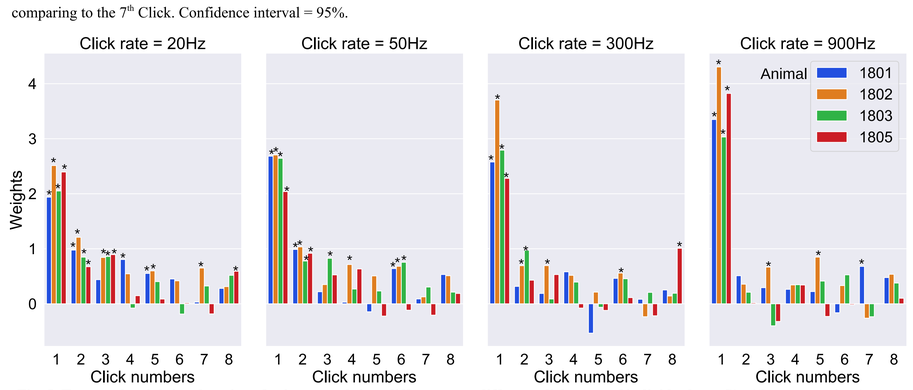

Fig. 5 Temporal weighting functions for interaural time differences at different click rates of individual rat. Significant onset dominance was seen across all click rates of all rats. The weights of the clicks following the first click increased as click rate decreased. Rat # 1805 showed significant weight on the last click at 20 Hz and 300 Hz. *: $P < 0.05$.

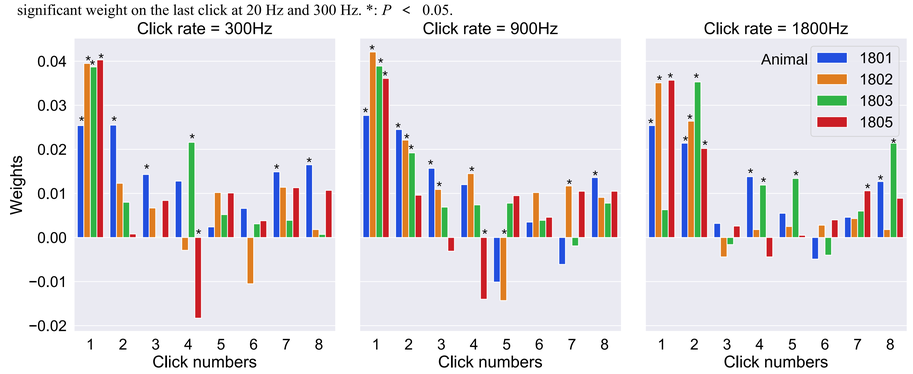

Fig.6 Temporal weighting functions for interaural level differences at different click rates of individual rat. Significant onset dominance was seen at 300 Hz and 900 Hz for all rats and at 1800 Hz for rat # 1801, # 1802, # 1805. The weights of the clicks following the first click increased as click rate increased. Rat # 1801 showed significant weight on the last click at 300 Hz, 900 Hz and 1800 Hz, while rat # 1803 at 1800 Hz. *: $P < 0.05$.

Conclusion

1. Onset dominance was observed in all rats at all the tested click rates for ITD stimuli and ILD stimuli, except rat # 1803 at 1800 Hz in ILD test.
2. The weights on the later clicks tended to increase as the click rate decreased for ITD stimuli, but as the click rate increased for ILD stimuli.
3. Significant weight on the last click (offset) was also found for ITD and ILD stimuli in a few cases.
4. Our findings demonstrate that the auditory process in rats is similar to that in humans, showing clear onset dominance and recency effects.
5. Therefore, we suggest that rat is a useful model in binaural hearing research for its similarity with humans and easy accessibility.

References

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