Zwicker Tone Illusion and Noise Reduction in the Auditory System

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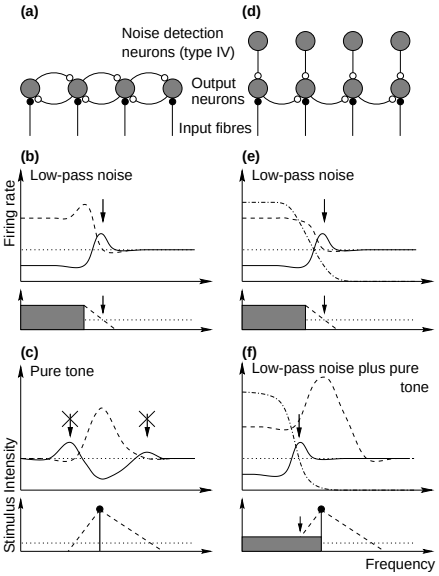
The Zwicker tone is an auditory aftereffect. For instance, after switching off a broad-band noise with a spectral gap, one perceives it as a lingering pure tone, the pitch being in the gap [1, 2]. It is a unique illusion in that it cannot be explained by properties of the auditory periphery alone and has no direct analog in the visual system either. Here we present psychoacoustic experiments that reveal the crucial role of noise [3, 4]. Habituation is ruled out as a driving mechanism. Furthermore, we propose a neuronal model that predicts both the pitch and whether a sound can generate a Zwicker tone at all. We show that dominantly unilateral inhibition in conjunction with a neuronal noise-reduction mechanism explains the effect.



The figure shows both habituation (left column) and noise reduction (right).
(a) Neuronal implementation of simple (symmetric) lateral inhibition. Grey circles denote neurons, small filled circles indicate excitatory synapses and small open circles inhibitory synapses.
(b),(c) Response (upper panel) of the habituation model (a) to two sounds shown in the lower panels. Firing rates of the neurons before (horizontal dotted line, spontaneous rate), during (dashed line) and immediately after (solid line) the sound presentation are shown schematically. Downward arrows indicate Zwicker tones predicted by the model. In the case of the pure tone in (c) the habituation model predicts even two Zwicker tones (crossed arrows) whereas in reality there is none.
(d) Neuronal implementation of the full model with asymmetric inhibition and noise detection.
(e),(f) Response (upper panels) of the model in (d) to two sounds (lower panels). Dash-dotted lines indicate schematic firing rates of noise-detection neurons.

[1] Zwicker, E. 'Negative afterimage' in hearing. *J. Acoust. Soc. Am.* **36**, 2413–2415 (1964).
[2] Zwicker, E. & Fastl, H. *Psychoacoustics: Facts and Models*. Springer, Berlin (1999).
[3] Franosch, J.-M. P., Kempter, R. & van Hemmen, J. L. Zwicker tone illusion and noise reduction in the auditory system (2000). Preprint TU München.
[4] Fastl, H., Patsouras, D., Franosch, J.-M. P. & van Hemmen, J. L. Zwicker tones for pure tone plus band limited noise. In *Physiological and Psychophysical Bases of Auditory Function, Proc. of the 12th International Symposium on Hearing*, pp. 57–63 (2000).