Brain and Music: Prediction in Music

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Research Question

My research question is based on Bitterman's research about prediction in music. She suggested to bridge the gap between the sound signal and its perceptual organization by identifying 'auditory objects'- separate entities related to things and events in the environment- with predictive models.

My research question: Are the results found by Bitterman derived from the surprise effect or by other possible factors like volume, preferred notes and pitch of notes and more.. ?

Background

To survive, organisms must extract information from the past that is relevant for their future. How this process is expressed at the neural level remains unclear. In previous studies, predictability has been shown to affect neuronal responses in many animals and under many conditions. Detecting unexpected stimuli in the environment is a critical function of the auditory system. Clearly, the quality of predictions should depend on the amount and detail of the past information used to generate them. Responses to unexpected "deviant" sounds are enhanced compared to responses to expected stimuli [1].

One of the primary roles of sensory processing is transformation - from the partial and ambiguous information provided by the sensory organs into a coherent, ethologically – relevant description of the sound sources in the environment. A major challenge to this process is the fact that in real life multiple sound sources are often concurrently active. The waveforms they emit reach our ears all mixed together with information possibly irrevocably lost. The task of the brain is to reverse this effect and decompose the sound mixture back into its components.

Auditory Scene Analysis (ASA), coined by Bregman (1990)[2], is the term currently used for various schemes that bridge the gap between the physical sound mixture and the introspective percept of hearing separate sources. The question is how a complex spectro-temporal pattern, the auditory scene, is segregated and grouped into separated perceptual units and objects.

The resulting perception is of an orderly 'auditory scene' that is organized into ethologically-relevant 'auditory objects', separate entities related to things and events in the environment.

[1] The Representation of Prediction Error in Auditory Cortex (2016) Jonathan Rubin1, Nachum Ulanovsky2, Israel Nelken1,3*, Naftali Tishby1,4

[2] Bregman AS (1990) Auditory scene analysis: The perceptual organization of sound.

Work Plan

November-December 2018
- Knowledge of data and understanding of data structure as he digitally stored in computer files
- Read articles and understand the subject

December 2018
- Learn models - how sound becomes neural activity?

January-April 2019
- Perform an audit analysis as a control for Bitterman's research
  - Mathematical-Statistic writing
  - Prediction for complex stimulations and comparison for results

April-July 2019
- Re-synthesize the stimuli and conduct a direct verification on the results of Bitterman`s experiment

Data

The data for my project has been collected by researchers in Nelken's Lab. These electrophysiological data were recorded in-vivo from the left auditory cortex of 6 adult female Sabra rats. The joint ethics committee (IACUC) for animal welfare of the Hebrew University and Hadassah Medical Center approved the study protocol.

Once the recording site was characterized in terms of its responses to pure tones, the piano recording of Musica Ricercata II by György Ligeti was played with 4 version at 20 dB attenuation. This piece was played consecutively 10 times with a short break between repetitions.

Recording sites were selected by their response to broad-band noise (BBN). The electrodes were driven into the cortex while presenting 200 ms BBN bursts (0-50 kHz) with an inter-stimulus time interval (ISI, onset to onset) of 500 ms and a level of 30 dB att. The LFP responses were averaged online, and the electrodes were positioned at a location and depth that showed large evoked LFP responses on as many electrodes as possible.

The data is digitally stored in computer files at a sampling rate of 44 kHz per channel.

Computational Tools

I will use an information theoretical framework and linear models to predict neuron`s responses.
There are different possible functions of the probability that can serve as surprise measure such that notes that are less expected generate a larger surprise. I will adopt the definition used by Bitternan - the negative log of the probability that is-

$$surprise_i = -\log(p_i)$$