Interactions between sensory, emotional, and executive brain regions during tasting

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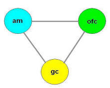
Introduction

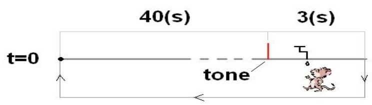


Taste perception is a complex process, involving integration of "bottom-up" information about the sensory stimulus with "top-down" information about the current hedonic and reward values of the stimuli.

Passive and self administration of tastes should therefore induce complex but different patterns of information transmission between gustatory cortex (gc), amygdala (am), and orbitofrontal cortex (ofc). Here, we present an initial investigation of these system dynamics, using simple correlations and Linear Granger Causality methods.

Method

•16-microwire electrode bundles were implanted into GC, BLA, and OFC under ket/xyl/ace anesthesia.
•7-day recovery from surgery.
•Awake, comfortably-restrained rats were trained to lever press for 40-µl aliquots of taste (see below).
-- an 8 kHz tone signalled taste availability
-- sucrose, NaCl, citric acid, quinine (selected randomly)
•Local field potentials (LFP) were recorded from each region before, during, and after trials.
-- 1000 Hz sampling rate
-- down-sampled to 50 Hz for Granger causality



Spectral Granger's Analysis

Spectral Granger's Analysis reveals the directional information flow from one signal to the other , at given frequencies.

Mathematically,for two time series signal $X_1(t)\ X_2(t)$

We build two regression models where the current value of the two signals are predicted not only by their owns previous data points, but also by the previous data points from the other signal.

$$X_1(t)=\sum_{j=1}^{p} A_{11,j}X_1(t-j)+\sum_{j=1}^{p} A_{12,j}X_2(t-j)+E_1(t)$$

$$X_2(t)=\sum_{j=1}^{p} A_{21,j}X_1(t-j)+\sum_{j=1}^{p} A_{22,j}X_2(t-j)+E_2(t)$$

$E(t)$ *Is the residual , and p is the order of the model*

Apply Fourier Transformation on the time domain model, we have the corresponding model in frequency domain

$$\begin{pmatrix}X_1(f)\\X_2(f)\end{pmatrix}=\begin{pmatrix}H_{11}(f) & H_{12}(f)\\H_{21}(f) & H_{22}(f)\end{pmatrix}\begin{pmatrix}E_1(f)\\E_2(f)\end{pmatrix}$$

H(f) is the transfer Matrix

The Power spectrum can then be calculated as

$$S(f)=\langle X(f)X^*(f)\rangle=\langle H(f)\sum H^*(f)\rangle$$

The Spectral Granger's causality is defined as

$$G-Causality_{j\to i}=-\ln\left(1-\frac{\left(\Sigma_{jj}-\frac{\Sigma_{ij}^2}{\Sigma_{ii}}\right)|H_{ij}(f)|^2}{S_{ii}(f)}\right)$$

Σ *is the covariance matrix of the residuals*

*** The Spectral Granger's Causality analysis in this study is based on the Matlab toolbox BSMART,**

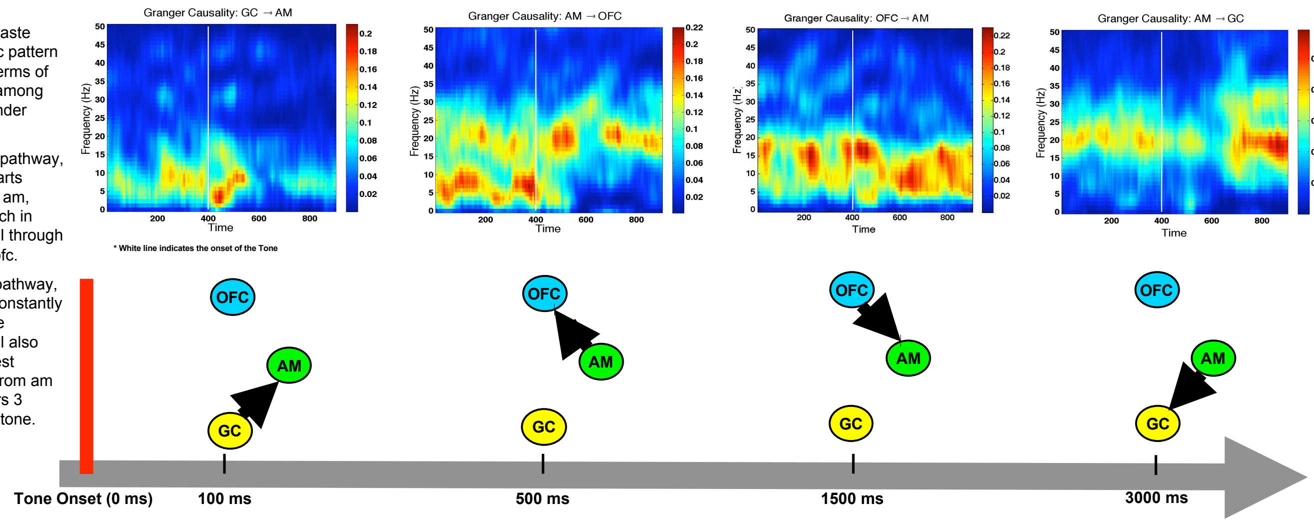
Jie Cui,2008, "BSMART: A Matlab/C toolbox for analysis of multi-channel neural times series", *Neural Networks, 2008* Special issue

Information Flow after the Tone

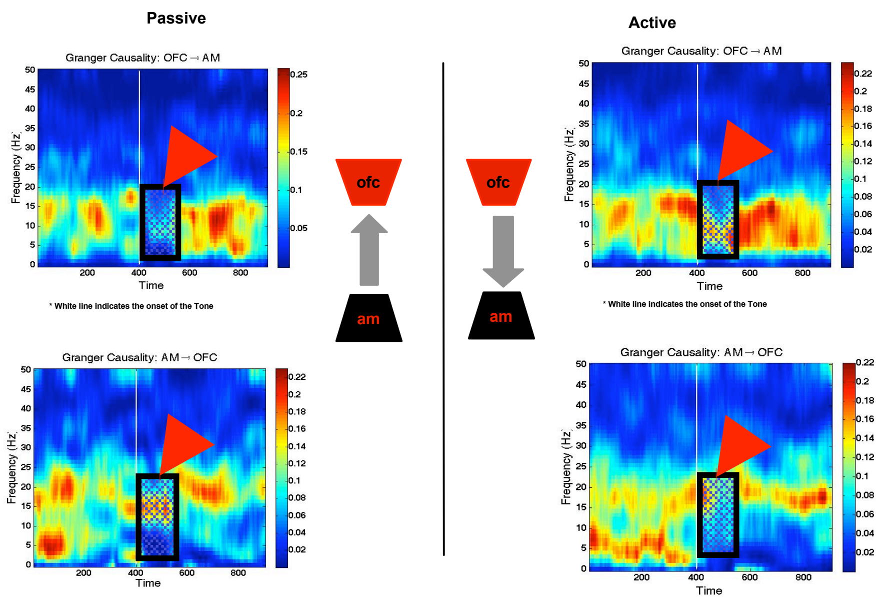
•The signal of the availability of the taste triggers a dynamic pattern of interaction, in terms of information flow, among the three areas under consideration.

•In the bottom-up pathway, the information starts flowing from gc to am, followed by a switch in frequency channel through which am drives ofc.

•In the top-down pathway, ofc seems to be constantly driving am, but the frequency channel also switched. The latest appeared flow is from am to gc, which occurs 3 seconds after the tone.



Comparison Between Active and Passive Case



• In the active case, the rat hears a tone, then press the lever and get the taste.
•In the passive case, the rats get the taste passively, without pressing the lever or hearing a tone.
•During the 1500ms period immediately after the animal gets the taste,the direction of information flow between ofc and am is opposite between active and passive case. In the Active case, it seems that the executive brain area (ofc) drives the emotional brain area (am), whereas in the passive case, the dominant information flow is from am to ofc.

Conclusions

•The current study quantitatively demonstrate the dynamics and the hierarchy of the information processing during self administered tasting.

• Spectral Granger's causality analysis shows a systematic pattern of timing of information flows among different brain areas involved in active tasting.

• The comparison between active and passive case suggests that the directional interaction between executive and emotional brain areas are critical to active tasting.

• The functional role of the switch in frequency channel through which information flows remain unclear, future study should address this phenomenon specifically revealed by causality analysis in frequency domain.