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Context sensitive stimulus coding in auditory cortex cellular mechanisms

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1 Introduction

On the level of auditory cortex the coding of stimuli is represented in a context sensitive fashion. This is obviously necessary in order to combine the stimulus features provided by the lower level auditory system into objects, separate stimuli belonging to different objects, sharpen the tuning to certain stimulus parameters on demand and to detect changes in the ongoing regime of stimuli.

In the topic I'm proposing here, a few cellular mechanisms that might participate in the implementation of this adaptive behaviour are elucidated. Overall the number of mechanisms involved might be very manifold, so I decided to focus this topic on mechanisms that can help understand how the modulation of stimulus coding on a timescale of tens of milliseconds to a few seconds might be implemented.

2 Why is this topic important ?

There is several reasons why one would want to study the mechanisms of context sensitive coding. First, for physiological work and attempts to unravel the neural codes used for stimulus representations in cortex, it is essential to include the modulatory effects preceeding stimuli might have on following stimuli on different time scales. Furthermore it might be possible to classify cells in cortex based on their role in context sensitivity and adaptive capabilities instead of the spectro-temporal receptive fields which are dynamic [2] due to context (task) sensitivity. Other observations including context-sensitive neural responses involve the coding of sound location [5] and sensitivity to temporal order of sounds [3].

Second, in psychophysical auditory studies context-sensitivity is commonly observed, often expressed in effects that depend on time or dissociative results for short and long delays in multiple interval experiments. In some cases also hyperacuity is observed, with little or no physiological correspondence. It has been shown that cortical cells can change their STRFs rapidly and that cortical circuits have descending projections reaching into the lowest levels of central auditory processing. It is conceivable that these descending projections can be used to sharpen sensitivity to certain stimulus parameters in a context-sensitive manner, thus making the understanding of context-sensitivity a key to understanding how the descending projections might be used and how psychophysical results might be interpreted.

Lastly, it is desirable to understand how information that is extracted from stimuli by lower level auditory circuits is integrated into higher-order neural representations before these are used by yet higher-order processing or encoded into various forms of memory. Context sensitivity seems to be a building block for just that. Also the context sensitive selection of information from stimuli is a form of neural processing that does not seem to occur on lower level parts of the central auditory system and is thus an interesting topic to elucidate.

3 Long-Lasting Modulation by Stimulus Context in Primate Auditory Cortex

In the article [1] the authors tested context-sensitivity to a number of stimulus parameters. They started using frequency and intensity, parameters known from forward masking. The then went on to vary the temporal structure of stimuli and also showed that modulation of subsequent stimuli could also be achieved using amplitude modulation as well as frequency modulation.They further studied the influence of the inter-stimulus interval, and found that modulations lasted up to about 2 seconds, placing these mechanisms at a shorter time-scale than working memory. Two other key findings include that facilitatory as well as suppressive modulation were observed, where the suppressive modulation was more common and is what has been known before. They further showed that there was no correlation between the firing rate of the first stimulus and the change in firing rate of the second stimulus, providing evidence that these modulatory effects are not “simple” neural adaptation but involve some more complex mechanisms.

4 Synaptic Mechanisms of Forward Suppression in Rat Auditory Cortex

As shown in psychophysical evidence and the paper by Bartlett et.al. [1], the implementation of the modulation requires mechanisms that last on time scales of up to 2 seconds. In the paper by Wehr et.al. [7] the authors demonstrate that in an awake animal GABAergic inhibition lasts only up to 100 ms, while at the same time suppressions of 500 ms and more are observed. It was previously thought that forward suppression is implemented by inhibitory mechanisms. They also antagonize the GABAergic pharmacologically and are not able to remove the suppression, providing a further line of evidence against inhibitory mechanisms. The authors then propose a mechanism of synaptic depression to play a key role in the forward suppression phenomenon.

5 Stimulus-Specific Adaptation

In [6] the authors describe neurons in primary auditory cortex that respond more strongly to rare stimuli. This phenomenon resembles strong similarity to the mismatch negativity MMN that is often studied using evoked potentials. The interesting point of this observation posed in ths paper is that it shows adaptation of neurons to the statistical distribution of stimuli. Another interesting observation in this paper is that the adaptation mechanism shows a hyperacuity for frequency discrimination. The cells analyzed in this study by the use of signal detection theory seem to be able to discriminate rare tones with a $\delta f = 0.04$ from the standard stimuli.

6 Hierarchical Organization of Auditory Temporal Context

Songbirds have a cortical area that has an extreme sensitivity to its own song, but not to other sounds. While this is an mechanism that has not been observed in primates or humans, it might provide for a good model of how temporal context sensitivity is implemented in cortical cells. Lewicki and Arthur [4] study area HVc and a an area of a lower level nucleus (area L) and test these with manipulated versions of the song bird. The authors show that there is also context sensitivity in the lower level areas but for shorter fragments of the song, thus establishing a hierarchical representation of context-sensitivity in order to span context-sensitivity over a long period of time, i.e. the entire song.

7 Suggested topic papers

As can be seen from the above listing of 4 mechanisms, the suggested papers are:

- *Long-Lasting Modulation by Stimulus Context in Primate Auditory Cortex.* Bartlett et.al [1]
- *Synaptic mechanisms of forward suppression in rat auditory cortex.* Wehr et.al [7]
- *Processing of low-probability sounds by cortical neurons.* Ulanovsky et.al [6]
- *Hierarchical organization of auditory temporal context sensitivity.* Lewicki et.al [4]

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