

HST.723J/9.285J - Neural Coding and Perception of Sound

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Hofman et al. (1998)

Spatial elevation cues are contained mainly in spectral changes caused by the direction-dependent filtering of the pinnae, head and shoulders. Everyone's ears are different and it has been shown that listening through someone else's ears often results in a severe deterioration of elevation judgments. In other words, some learning or adjustment to one's own ears must go on. This study shows that such learning can take place over a matter of days or weeks. By inserting molds into the subjects' ears, the authors were able to disrupt the normal elevation cues, resulting in initially very poor elevation acuity. However, after wearing the molds continuously for (in some cases) up to 6 weeks (!), performance approached pre-mold levels. What does the observation that good performance was again achieved immediately after removal of the molds tell us?

Warren and Griffiths (2003)

In this fMRI study of human auditory cortex, Warren and Griffiths demonstrate spatially distinct cortical areas involved in processing pitch sequences and spatial sequences. The motivation for the study is twofold. First, the authors are interested in understanding the division of functions within the planum temporale (PT), an auditory cortical region composed of non-primary areas and located posterolateral to Heschl's gyrus (the site of primary auditory cortex). Second, they are interested in testing the idea that there are separate pathways for analyzing "where" a sound comes from and for analyzing "what" produces a sound. A division of "what" and "where" processing has been found in the visual system and has been suggested by some to also apply to the auditory system. The experiments involved presenting stimuli (iterated ripple noise) with changing pitch, changing spatial location (simulated using head-related transfer functions), or a combination of both. The results showed that pitch changes (but not spatial location changes) activate anterior PT while location changes (but not pitch changes) activate posterior PT. Insofar as pitch is used for object recognition, the results support the idea that auditory "what" and "where" are analyzed in separate anterior and posterior processing streams.

Belin et al. (2000)

- This study looked for brain areas involved in the analysis of human voices. The brain activity produced by vocal and non-vocal sounds was compared using fMRI. "Voice-selective" areas were identified in non-primary auditory cortex.
- The authors suggest that these voice-selective areas may be analogous to face-selective areas in the visual system. They also suggest that there could be similar voice-selective areas in non-human species. Do you agree?
- You can find related papers and download the stimuli for this paper (if using Windows) from www.zlab.mcgill.ca. (Go to publications, 1997-2002, and click

on "supplementary materials" for this paper.)

Kamke, Brown, and Irvine (2003)

- This study explores the tonotopic mapping of the ventral division of the medial geniculate body (MGv) in the thalamus. The experiments are performed in normal cats and in other cats that have high-frequency hearing loss caused by damage to the cochlea.
- After hearing loss, there was a large change in the tonotopic map, with an expanded region of the MGv devoted to characteristic frequencies near the edge of the lesion. This re-organization is usually called “plasticity” because something that is plastic can be re-shaped. Note that the expanded region had near-normal thresholds.
- Analogous plasticity has been observed in previous studies of the auditory cortex. Since there are extensive “descending” connections from the cortex to the thalamus, the plasticity seen in this study could result from a “top-down” process. Alternatively, the plasticity in thalamus could cause the plasticity in cortex via a “bottom-up” process.

Fritz et al. (2003)

- This study examined receptive fields of cortical neurons during a behavioral task and determined that there was “task-related plasticity” in the receptive fields. In other words, it showed that receptive fields changed depending on behavioral state of the animal. This type of “plasticity” is on a quick time scale of minutes, much faster than the hearing-loss-related plasticity of cortical tonotopy that we discussed in lecture.
- Neurons were recorded from the cortex of awake ferrets. Spectrotemporal receptive fields were determined using broadband stimuli. This type of receptive field takes into account not only the frequency of the stimulus but also its temporal properties (amplitude envelope).
- The ferrets were trained to lick a water spout during the presentation of reference sounds (broadband stimuli) and to refrain from licking when they heard a target sound (tonal stimulus whose frequency could be chosen by the experimenter). A unit’s receptive field was measured, and the target frequency was chosen so as to be initially outside the receptive field. As the animal attended to that particular frequency (because it was important for the behavioral task) the receptive field could change so as to now encompass the target frequency. Results similar to these have been demonstrated for visual cortex neurons, but perhaps only once previously for auditory cortex neurons.

Bao et al. (2004)

- This study explores the plasticity in processing of acoustic stimuli presented in rapid succession by neurons in the auditory cortex. Recordings were made from A1 in rats.
- The rats were trained in a “sound maze”, in which the rat has to find its way to a target to obtain a food reward. The rat’s proximity to the target was signaled by an increase in repetition rate of noise bursts: slowly presented noise bursts signals that the rat is far away from target; rapidly presented noise bursts signals that the rat is close to target. The rats performance on the task improved over the course of a month. Control animals were placed in a similar sound situation but not required to go through the maze to obtain the reward).
- Recordings from the trained rats showed better following of responses to rapidly presented noise bursts. For example, for the high rates of 15-20 noise bursts/sec, there was a large response to each noise burst. In naïve or control animals, the response to these “high” pulse rates was smaller (note that for lower levels of the auditory pathway these rates aren’t particularly high; it’s just that normally in the auditory cortex the following ability of neurons to these pulse rates is low).
- Responses were also better “phase locked” to the high rate noise bursts. Note that here the phase locking is defined differently than what we have used previously – the vector strength used quantifies how well the spikes were time-locked to the noise bursts (rather than to individual stimulus cycles as conventionally used).
- The results suggest that training has indeed improved the temporal processing ability of neurons in the auditory cortex. Such plasticity appears to be a hallmark of the auditory cortex and other centers at the highest level of the auditory pathway.