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Neural mechanisms underlying auditory cognition

How do we perceive the auditory world and make sense from the myriad of concurrent sounds in the noisy and complex soundscape impinging our ears at a given moment in time? Recent research has suggested that the auditory system extracts regularities from the ongoing acoustic input to build up auditory object representations. A large number of studies using the so-called oddball paradigm have demonstrated that the occurrence of an unexpected change in an otherwise repetitive sequence of sounds elicits a component of the cortical auditory evoked potential termed Mismatch Negativity (MMN). In the oddball paradigm, a particular "standard" stimulus is presented as with a high probability of occurrence, whereas a different stimulus, the "deviant" occurs with a low probability. The elicitation of the MMN to the deviant stimuli is taken as the evidence that the auditory system has built up a regularity representation on the invariance in the preceding sound sequence. Similar results are obtained with the roving-standard paradigm, which allows a more direct examination of the mechanisms of regularity encoding.

As the MMN has shown to have cortical generators, the function of regularity encoding and deviance detection has been suggested to pertain to high level cognition, in agreement with single neuron activity exhibiting stimulus-specific adaptation (SSA) in primary auditory cortex. Yet recordings in the inferior colliculus and the auditory thalamus of experimental animals have disclosed SSA at these levels of the ascending auditory pathway, challenging the corticocentric view of regularity encoding and deviance detection. In addition, recent experiments from my laboratory implementing the oddball paradigm, but setting the stimulation, the recording and the analysis parameters to measure the complex Auditory Brainstem Response (cABR), the Middle Latency Response (MLR) of the auditory evoked potential, and their Magnetoencephalographic (MEG) and functional Magnetic Resonance Imaging (fMRI) correlates, have supported this emerging view of subcortical cognition in audition. In these experiments, the so-called reversed oddball condition, in which the stimuli that had the role of deviant in the oddball condition were presented as standards, and a critical control condition, featuring different sounds with the same low probability of the deviant to control for refractoriness effects, were implemented.

In my talk I will try to summarize all these studies that show that human auditory deviance detection based on regularity encoding occurs at latencies and in neural networks comparable to those revealed in animal studies of single-neuron activity. These studies demonstrate that the encoding of simple acoustic-feature regularities and detection of corresponding deviance, such as an infrequent change in frequency or location, occur in the latency range of the MLR, in separate auditory cortical regions from those generating the MMN, and even at the level of human auditory brainstem, as indicated by the cABR. In contrast, violations of more complex regularities, such as those defined by the alternation of two different tones or by feature conjunctions (i.e., frequency and location) fail to elicit MLR correlates but elicit sizable MMNs. Taken together, these studies give support to the emerging view that regularity encoding, as revealed by deviance detection, is a basic principle of the functional organization of the auditory system, one that it is organized in ascending levels of complexity along the auditory pathway expanding from the brainstem up to higher-order areas of the cerebral cortex.