Our brain is constantly doing statistics without us knowing about it

An evolutionarily old auditory brain structure keeps track of sound statistics

Each place has its associated soundtrack. Learning these soundtracks requires knowing the probabilities of context-sound associations. That we learn these automatically reflects the fact that our brain is good at statistics. To date it was not known where in the brain this process takes place but typically it is assumed that long-term learning involves the brain's cortical structures. Yet, researchers in Göttingen have found that the auditory midbrain, an evolutionarily old and subcortical structure in the brain, can learn these sound-context associations and their probabilities.

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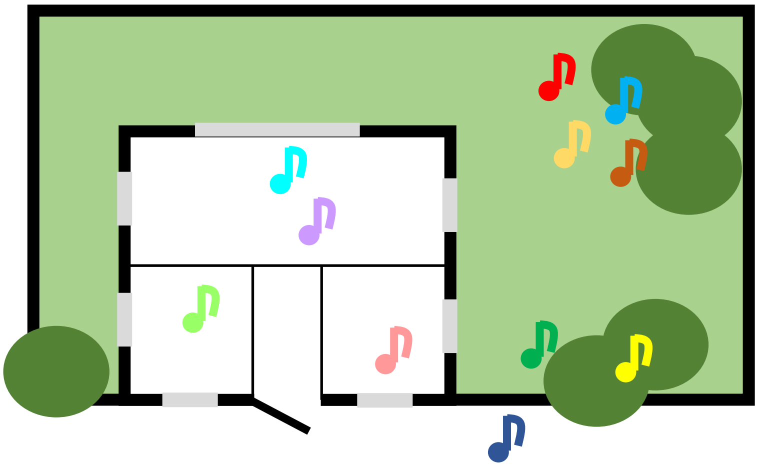
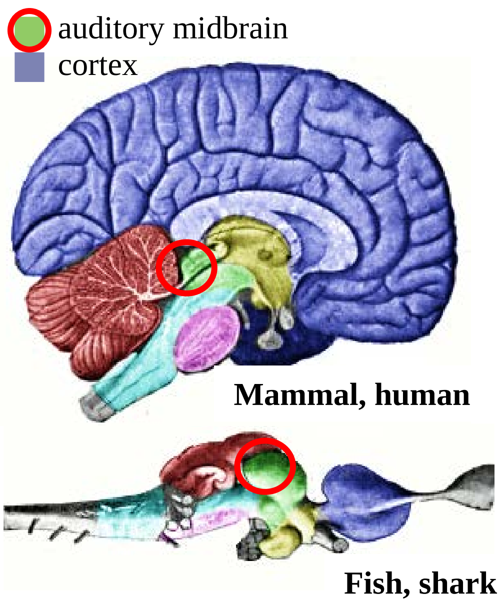


The market on a Saturday does not sound like a forest at night. Each place has a characteristic soundtrack, which we learn unaware and use to interpret what is happening around us. For example, while in the sitting-room, we can recognize the person walking through the front door from the sound of their steps. Knowing about the sound patterns that characterize each location is knowing about statistics, about the probabilities that particular sets of sounds occur in that context. If we expect a particular sound in a particular setting it is because we have learnt that the probability of its occurrence is high in that setting.



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Which part of our brain performs statistical learning? The sensory organs transfer decoded information about colours, sounds or other sensations first to subcortical structures, which are evolutionarily older than cortex. The result of this processing is then sent to the cortex which is believed to deal with progressively more complex and temporally demanding stimuli combinations and to make decisions. Several studies have shown that different structures in the auditory pathway –from the ear to the auditory cortex– are sensitive to the short-term history in the sound stream. This is reflected the fact that we 'stop hearing' sounds that are constantly repeated, such as a ticking clock or a nearby motorway, a process known as response adaptation.

But we can also learn patterns made by sounds to which we are exposed in short and temporally isolated bouts. This is the case of context-associated sounds. The sound that a specific chair makes when we sit on it, or the sound our steps make on a particular spot on the corridor floor are sounds that we are not exposed to constantly but rather in temporally isolated instances and for a short time. Yet, we can learn these context-sound associations across these isolated exposures. Which area of the brain performs this learning was not known but, typically, long-term detection of regularities is attributed to cortical structures.

The lab of Livia de Hoz, at the Max Planck Institute of Experimental Medicine in Göttingen, has found that statistical learning of context-sound associations occurs in the auditory midbrain, a subcortical station in the auditory system. The auditory midbrain is older than the mammalian cortex and, in mammals like us, is a necessary sound processing station before information arrives in the cortex.

In the auditory system, neurons respond strongly to some sounds and not to others, and different neurons prefer different sounds. What Hugo Cruces-Solís and colleagues found is that neurons in the auditory midbrain of mice that lived in a multi-compartment environment, became more active in response to sounds if the mice had heard a specific tone every time they entered one of the compartments. The neurons of mice that were exposed to the same sound but in a random manner changed their responses in a different way, indicating that neurons in the auditory midbrain are sensitive to the predictability of the sound. Responses to tones were increased in the mice that heard context-specific sounds independently of whether the neurons were sensitive to that sound or not: neurons became less selective. Yet, at the same time, those neurons that preferred the context-specific sound responded also with less variability, making the decoding of sounds more accurate. Thus, the combined activity of the population of neurons ameliorated both the capacity to generalize across sounds and to discriminate between them. Overall the data suggest that the observed changes in coding modulate the way context-specific sounds are perceived and the behavioural responses they lead to.

The subcortical auditory system plays, therefore, a significant role in the detection of statistical regularities in context-sound associations, something of great relevance for our interpretation of the meaning of surrounding auditory stimuli and, therefore, of the world.

Cruces-Solís H, Jing Z, Babaev O, Rubin J, Krueger-Burg D, Strenzke N, de Hoz L.
Auditory midbrain coding of statistical learning that results from discontinuous sensory stimulation.
PLoS Biology.