

How the bat brain detects novel sounds (commentary on Wetekam et al., 2021)

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What is it like to be a bat? This is a question that has haunted philosophers and neuroscientists for decades (Nagel, 1974; Ulanovsky & Moss, 2008). We will probably never have a full answer to the above question (for bats, or any other organism). What we can know, however, is what happens in the bat brain when the animal listens to sounds or performs actions.

Interest in bats as a model organism started as early as 1794, when the Italian priest Lazzaro Spallanzani first described bats' ability to navigate in the dark (Spallanzani & Vassalli, 1794). This ability was later termed echolocation (Griffin, 1958). The most interesting thing about experiments in bats is the link between the bats' unique behaviours and specializations in the brain. This has led to several discoveries, including large areas dedicated to echolocation in the bat cochlea and central auditory system (Hechavarría et al., 2013; Kössl & Vater, 1985; Suga & Jen, 1976; Suga & O'Neill, 1979; Wenstrup & Portfors, 2011); the description of three-dimensional place cells in the bat hippocampus (Yartsev & Ulanovsky, 2013); dynamic neural networks that enable the production and modulation of echolocation sounds (Weineck et al., 2020);

and circuits for social interactions that are important in bats (Rose et al., 2021; Zhang & Yartsev, 2019).

Detection of deviant stimuli and the underlying neural mechanism is one study area in which bats have not been used extensively as an animal model. Deviance detection, studied in humans with EEG recordings, appears as a mismatch negativity (MMN) signal occurring in response to an unexpected sensory event (Näätänen et al., 1978). MMN can be measured at birth, and it occurs in wakefulness, sleep, and even in coma (Koelsch et al., 2006; Morlet & Fischer, 2014; Nashida et al., 2000). Deviance detection has been studied in laboratory animals (mostly rats and mice) at the single neuron level, where it takes the form of stimulus-specific adaptation (SSA; Nieto-Diego & Malmierca, 2016; Parras et al., 2017; Ulanovsky et al., 2003). SSA and MMN may be linked to each other and may be the microscopic and macroscopic manifestations of the same physiological mechanism of deviance detection (Carbajal & Malmierca, 2018; Nelken & Ulanovsky, 2007). SSA and MMN have received particular attention in the auditory domain with several studies linking these two phenomena to predictive coding theory (Malmierca & Auksztulewicz, 2021; Parras et al., 2017).

So, what could the study of bats contribute to our understanding of deviance detection? One possible

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answer is *neuroethology*. An animal model that uses rich vocal repertoires to communicate and navigate could help us correlate the strength and dynamics of SSA/MMN responses with the signals' behavioural value. There have been few investigations of deviance detection in bats. We know that a subpopulation of neurons in the bat midbrain display stimulus-specific adaptation to artificial sounds, very similar to that found in laboratory rodents (Thomas et al., 2012). The occurrence of unexpected natural sounds, such as echolocation sounds following a sequence of communication calls, and vice versa, also elicit responses in the bat cortex that resemble deviance detection signals (López-Jury et al., 2021).

A new study of deviance detection in bats appears in this issue of *European Journal of Neuroscience*. Wetekam et al. (2021) present a characterization of brain activity in fruit bats (*Carollia perspicillata*). The authors use auditory brainstem responses (ABRs) to investigate the correlates of deviance detection in the bat ascending auditory pathway. This technique is common in human studies and has been used previously to study deviance detection in rodents (Duque et al., 2018). Wetekam et al. report that the underlying mechanisms of deviance detection vary in a frequency-specific manner in bats and are very much related to the physical structure of echolocation and communication sounds used by the animals in their natural habitats. The latter point shows the value of neuroethology for understanding how the brain copes with sensory stimuli. The article also concludes that deviance detection in bat ABR signals is best decoded from slow waves. Slow waves are often overlooked in ABR studies as they filter out slow components (i.e., <300 Hz). The origin of slow waves in ABRs may bear further investigation, especially if they illustrate a method to study complex phenomena, such as deviance detection, with minimally invasive techniques that are useful across model organisms.

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CONFLICT OF INTEREST

The author declares no conflicts of interest.

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