learned neural sequences are stable. A musician may activate muscles in a fast sequence with a remarkable stereotypy that persists for years. However, little is known about the stability of the underlying neural patterns over these time scales. Do the same microscopic (i.e. single cell) or mesoscopic (i.e. multi-unit) patterns of neural activity persist across time at central levels of motor control, or does the brain drift among “degenerate” states that produce the same effective muscle output? The answer to this question will vary depending on the system considered. We continuously monitored neural activity from the cortical pre-motor nucleus HVC in awake-behaving zebra finches both in bilateral and unilateral implants, using minimally invasive carbon-fiber electrodes. The recordings reveal a detailed pattern of neural activity stereotyped on a 5 ms time scale that is synchronous between the two hemispheres. These stereotyped patterns persist for months. Furthermore, after nerve damage to the syrinx (vocal organ), we find evidence that central motor patterns remain unchanged for a minimum of one month, despite disruption of the acoustic form of the song. We conclude that the neural correlates of song include both precise single unit firing and stable mesoscopic, patterns. Here we describe progress towards understanding the relationship between these two levels of motor representation.

III-70. Are grid-cell responses very low-dimensional?

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What mechanisms could underlie grid cell activity in rodents is the subject of debate, with different models positing starkly divergent neural architectures and dynamics. One model class is based on the conversion of cellular temporal oscillations into spatially periodic responses, while another is based on strong lateral network connectivity that leads to low-dimensional periodic pattern formation in the neural population, which is then converted into periodic spatial responses. Despite these differences, current analyses of experimental data have not ruled out either model. We examine spikes from multiple simultaneously recorded grid cells, with the aim of elucidating the dynamics underlying grid cell activity. We demonstrate evidence of a 2-dimensional continuous attractor in the response of grid cells to animal location. The responses of grid cells with similar spatial period are identical (upto measurement uncertainty), differing from each other along only 2 dimensions of their response, through translations of their preferred spatial phases. The relationships between grid cell responses – specifically, their relative spatial phases – remain absolutely stable (upto measurement error) over time, even if the responses themselves do not. Relative phases remain absolutely stable when the grids are significantly deformed by anisotropic stretching in response to a rapid resizing of the environment, as well as when the grids uniformly expand in novel environments. The stabilization of relative phase during dramatic changes in single-cell responses cannot be ascribed to input from external cues or from the hippocampus, because we ascertain that relative phases are stable even when these inputs are not. The findings together provide unequivocal support for the hypothesis that the brain computes using low-dimensional continuous attractors. Finally, we assess the implications for proposed mechanisms of grid cell activity, and show that the data specifically support the pattern-forming recurrent network models.