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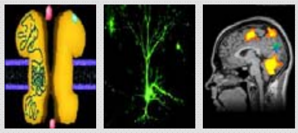

Molecular and Neural Correlates of Memory and Cognition

April 9 - 10, 2019 Veranstaltungszentrum, Ruhr University Bochum

Wednesday April 10, 9:15 – 12:00

Session 3 **Subcortical contributions to memory and cognition**

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A gravity-based three-dimensional compass in the mouse brain

Head direction (HD) cells, which encode allocentric head orientation analogous to a “neural compass” as they become active whenever the animal’s head points to a particular direction, is a fundamental component of the spatial navigation system. Adaptation to life on earth makes gravity a veridical allocentric cue for the brain’s compass. Nevertheless, HD cells have been traditionally known for encoding head orientation in the horizontal plane (azimuth). It was not until very recently that HD cells in the bat presubiculum were shown to also respond preferentially to particular combinations of azimuth and pitch or roll tilt (Finkelstein et al., 2015). However, how pitch/roll tuning is defined and whether vertical orientation tuning of HD cells is anchored to gravity has not been tested. Furthermore, 3D orientation tuning has never before been demonstrated in rodents; and it may therefore be restricted to aerial and tree-dwelling species like bats.

In parallel to the studies in bat presubiculum HD cells, Laurens et al. (2016) identified gravity-anchored tilt tuning in the anterior thalamus of rhesus macaques and proposed that gravity-anchored tilt signals and visually-anchored azimuth signals converge onto HD cells to yield a sense of 3D head orientation (Laurens and Angelaki, 2018). However, as Laurens et al. (2016) did not test whether gravity-tuned cells are traditional, azimuth-tuned HD cells, the two observations (gravity-anchored tilt tuning in macaques and 3D HD tuning in bats) have remained segregated and largely independent.

We summarize strong experimental support for a common origin of the observations made in the bat presubiculum and the monkey anterior thalamus. We test the hypothesis that the neural compass in the mouse brain is also three-dimensional (3D) and we demonstrate that this 3D compass uses a coordinate system that is defined by the single allocentrically ubiquitous reference: gravity. As in bats, we show that HD cells in the mouse anterior thalamus, retrosplenial cortex and cingulum are tuned to combinations of azimuth and pitch/roll tilt. Thus, a 3D orientation compass is not a capricious property of flying mammals, but may instead represent a ubiquitous property throughout many chapters of animal evolution. Remarkably, we further show that both azimuth and pitch/roll tuning is anchored to gravity, the universal orientation constancy landmark of terrestrial life.