Spatial Cognition

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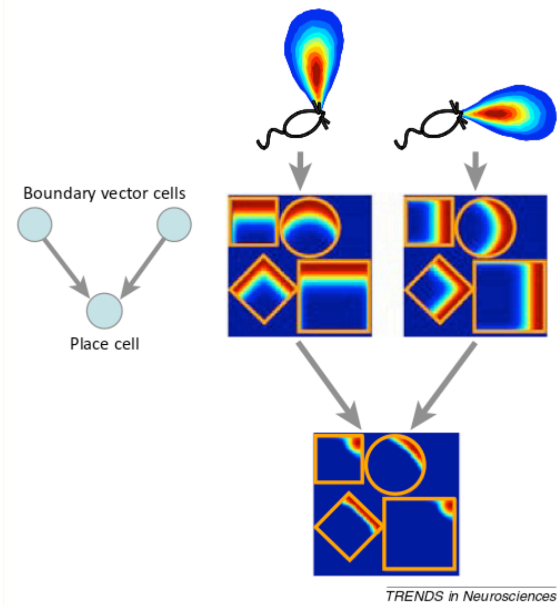
# What do grid cells contribute to place cell firing?

Bush D, Barry C, Burgess N. (2014) Trends in Neuroscience, 37:136-145.

A crucial part of the Spatial Cognition project investigates the transformations between retinotopic, head-centred and body-centred reference frames, with a special focus on the visual system. To link these perceptually driven processes to cognitive operations like memory a final transformation from a body-centred or head-centred (i.e. egocentric) frame to an allocentric reference frame needs to occur, allowing an organism to encode a view-point independent memory. Our model of spatial memory and imagery (Byrne et al. 2007) relies particularly on two types of spatially selective cells. First, place cells (neurons that are active in a circumscribed part of an environment, bottom panels in figure) and second, its main cortical inputs, the so-called boundary vector cells (BVCs, middle panels in figure). However, place cells also receive inputs from grid cells (exhibiting multiple isolated firing fields on a hexagonal grid), which are thought to underlie 2D path integration. The article portrayed here critically assesses the contributions to place cell firing provided by grid cells as opposed to boundary vector cells. The firing characteristics of hippocampal place cells are often thought to be reliant on inputs from grid cells. However, recent research has confirmed that environmental sensory inputs are crucial to place cells firing characteristics. In this view grid cells, which reside in the medial enthorinal cortex (mEC), most likely provide a complementary self-motion related signal that will contribute to place cell firing. However, the persistence of place cell activity after mEC lesions confirms that place cell firing must also be supported by other inputs. Similarly, removing inputs to the hippocampal subfield CA1, which originate in the subfield CA3, does abolish place cells activity in CA1, in both novel and familiar environments. Changes in firing rates of a place cell ensemble are not associated with corresponding changes in grid cells. Several other changes which can occur in grid cells (e.g. expanding grids in novel environments and dependence of grids on the theta rhythm) are not reflected in place cells. All these findings support the notion that hippocampal place cell responses must be maintained by other inputs. The boundary vector cell is a principle candidate for this role. It has been shown that the responses of place cells to boundaries and barriers are consistent with the model that posits boundary vector cell inputs as the main driver of place cell activity. These cells can not only respond to any boundary, but can also develop specificity to environmental features, thus explaining the evolution of place cell firing as an environment becomes more familiar (place cells loose secondary firing location in these situations). Moreover, the allocentric coding of boundaries, barriers and possibly objects by boundary vector cells would be a crucial constituent of any model, which endeavours to explain how space is represented in the brain, how this representation underlies imagery, and how it is eventually encoded in long term memory (Byrne et al. 2007).




A model of sensory driven place cell firing. Top: boundary vector cells (BVCs) have receptive fields in a fixed allocentric direction at a fixed distance from the animal. Middle: Recording the activity over time of BVCs as an animal moves in an environment (orange boxes) yields band shaped firing rate maps close to boundaries. Bottom: summing and thresholding the inputs of different BVCs yields place cell firing rate maps.

*References:*

Bush D, Barry C, Burgess N. (2014) “What do grid cells contribute to place cell firing?” Trends in Neuroscience, 37:136-145. (and references therein)

Byrne, Patrick, Suzanna Becker, and Neil Burgess. (2007) "Remembering the past and imagining the future: a neural model of spatial memory and imagery." Psychological review 114.2: 340.