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A RODENT NAVIGATION MODEL THAT COMBINES PLACE CODE, HEAD DIRECTION, AND PATH INTEGRATION INFORMATION.
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This model, utilizing coupled mechanisms for place recognition, maintenance of head direction, and path integration, replicates a variety of rodent behavioral and neurophysiological data. We simulated experiments by Collett, Cartwright, and Smith on gerbils performing a family of open-field landmark-based search tasks, and experiments by Cheng on rats navigating to a goal location in a rectangular arena.

Experiments by Mittelstaedt & Mittelstaedt have shown that gerbils possess a path integration faculty allowing them to follow a direct trajectory back to the nest after performing a random search. Presumably the animal's position in some internal coordinate system is being updated with each motor action. Although the neural basis of this ability is unknown, it clearly requires an accurate sense of head direction. Head direction cells have been found in several areas of the rat brain.

In addition to a path integrator and units coding for head direction, our model contains units with place fields controlled by visual landmarks, reflecting properties of hippocampal pyramidal cells. However, unlike other models of place cells, our model also accounts for the persistence of place fields in the absence of any visual input, by allowing place units to be driven by the path integrator. Thus, in our theory, the role of the hippocampal formation is to learn associations between external state (views of landmarks) and internal state (path integrator coordinates). Visual cues, when available, drive the place units, which can then correct for drift in the path integrator or reset it to a known value when the animal is first placed in a familiar apparatus, such as a radial maze.

Our model shows how allocentric bearings derived from head direction can be used to disambiguate visually identical landmarks, replicating the gerbil and rat data. Conversely, local view information can be used to correct for drift in the head direction estimate. Parallel relaxation among place units produces a consistent place code even when the model is presented with a distorted landmark array, emulating the robustness that animals show in novel situations. Parts of the model have been implemented on a mobile robot.