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Spatial uncertainty provides a unifying account of navigation behavior and grid field deformations

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To localize ourselves in an environment for spatial navigation, we rely on vision and self-motion inputs, which only provide noisy and partial information. It is unknown how the resulting uncertainty affects navigation behavior and neural representations. Here we show that spatial uncertainty underlies key effects of environmental geometry on navigation behavior and grid field deformations.

We develop an ideal observer model, which continually updates probabilistic beliefs about its allocentric location by optimally combining noisy egocentric visual and self-motion inputs via Bayesian filtering. This model directly yields predictions for navigation behavior and also predicts neural responses under population coding of location uncertainty. We simulate this model numerically under manipulations of a major source of uncertainty, environmental geometry, and support our simulations by analytic derivations for its most salient qualitative features. We show that our model correctly predicts a wide range of experimentally observed effects of the environmental geometry and its change on homing response distribution and grid field deformation.

Thus, our model provides a unifying, normative account for the dependence of homing behavior and grid fields on environmental geometry, and identifies the unavoidable uncertainty in navigation as a key factor underlying these diverse phenomena.

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