Head Direction Signals During Navigation: Comparing Movement and Stationary Periods

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Questions

- Can we use a machine learning classifier to predict a person's head direction at any given moment?
- Is the classification strength of head direction signals related to individual navigation performance?

Predictions

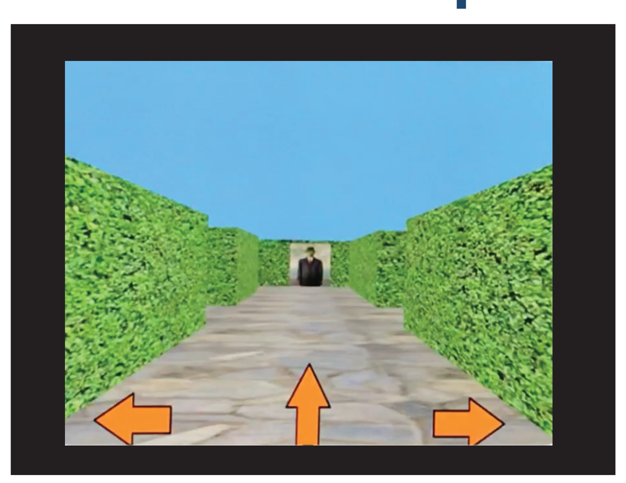
In a virtual navigation task, head direction signals can be classified in distributed brain regions: retrosplenial cortex, precuneus, thalamus, subregions of extrastriate cortex related to optic flow (e.g., MT, MST, and V3A), and early visual cortex.

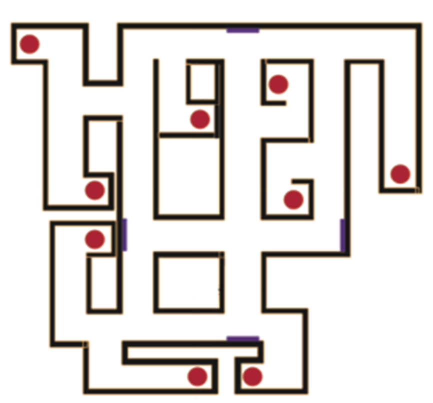
Background

- In rodents, head direction cells were discovered that selectively fire in the direction a rat is facing toward, independent of its location (Ranck Jr, 1984; Taube et al., 1990)
- In humans, head direction signals have been discovered in complex environments using repetition suppression of direction-related images (Shine et al., 2016, Cardin et al., 2013)
- In humans, head direction signals have been classified when exploring in a virtual open space (Koch et al., 2020, Nau et al., 2020)
- Multivariate pattern analysis (MVPA): a diverse set of methods that analyze neural responses as patterns of activity that reflect the varying brain states that a cortical field or system can produce (Haxby., 2012)
- Beta series analysis: it tracks the event-to-event hemodynamic fluctuations modeled in task fMRI

Methods

Task - Exploration



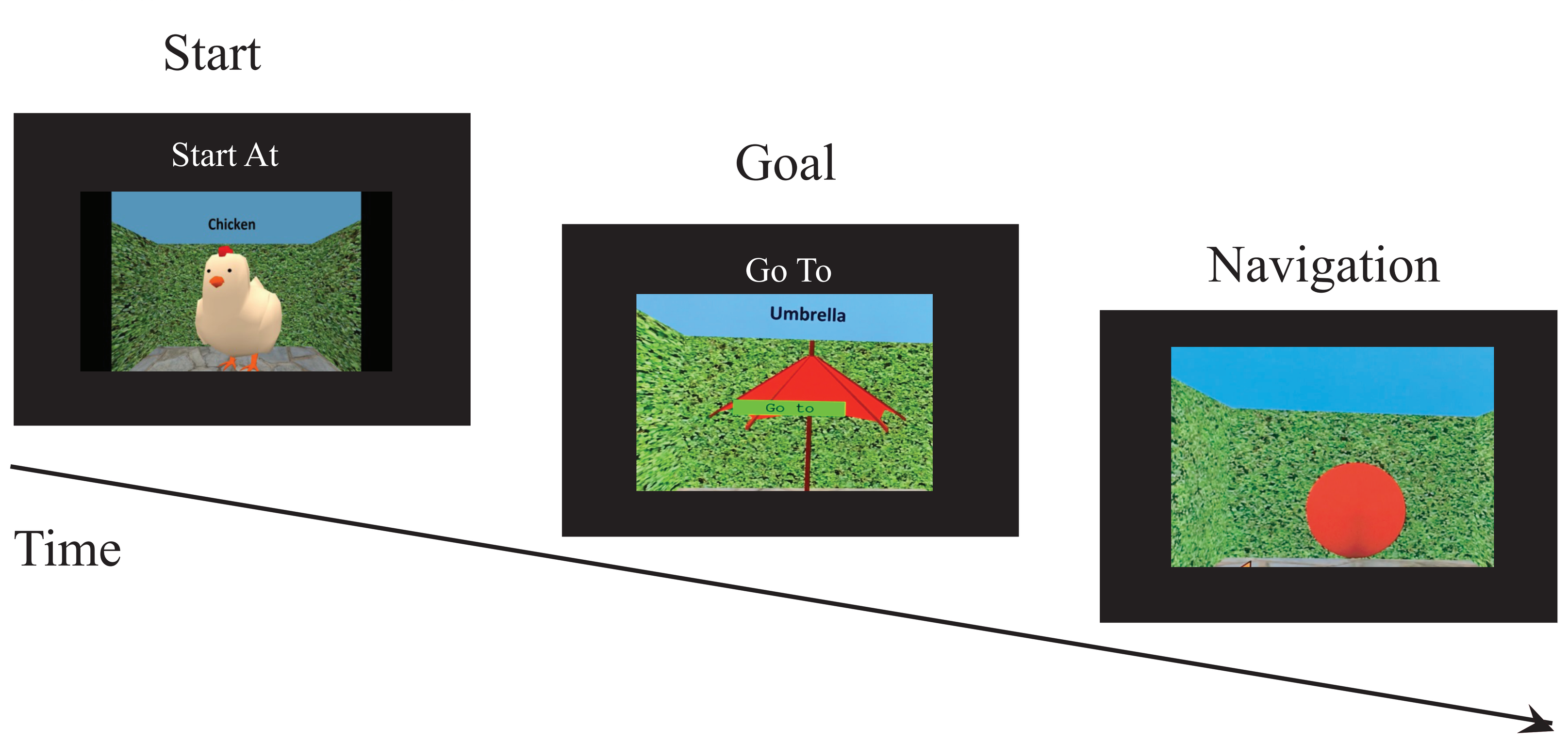


A Bird's Eye View of the Maze

A Video Clip of the Test Trial

- N = 98 healthy young adults
- 2 8-minute free exploration
- Find all 9 objects and learn their locations
- Make discrete button press at each choice point
- 8 trials each scan (48 total)
- Move in 4 cardinal directions (N, E, S, W)
- 6 test fMRI scans, self-paced

Task - Test



- Navigate from one object to another using paths of maze
- Preprocessed with fMRIprep
- Beta series with nibetaseries
- MVPA with Scikit-learn Gaussian Kernelized Support Vector Machine
- Chance level: MVPA based on randomly permutated events
- Atlases: subcortical (Harvard-Oxford) cortical (Schaefer2018)

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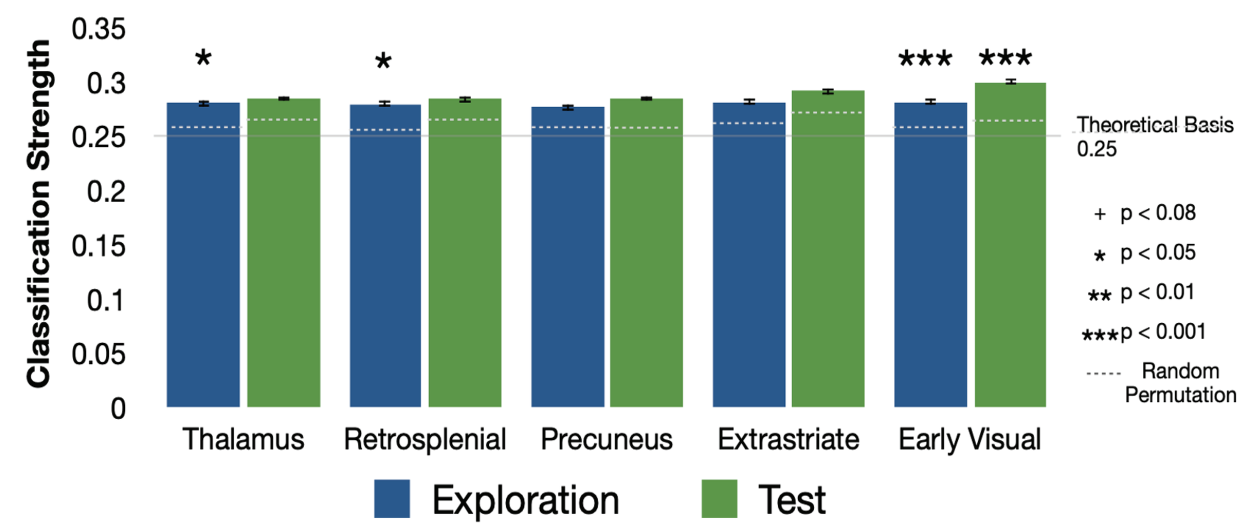
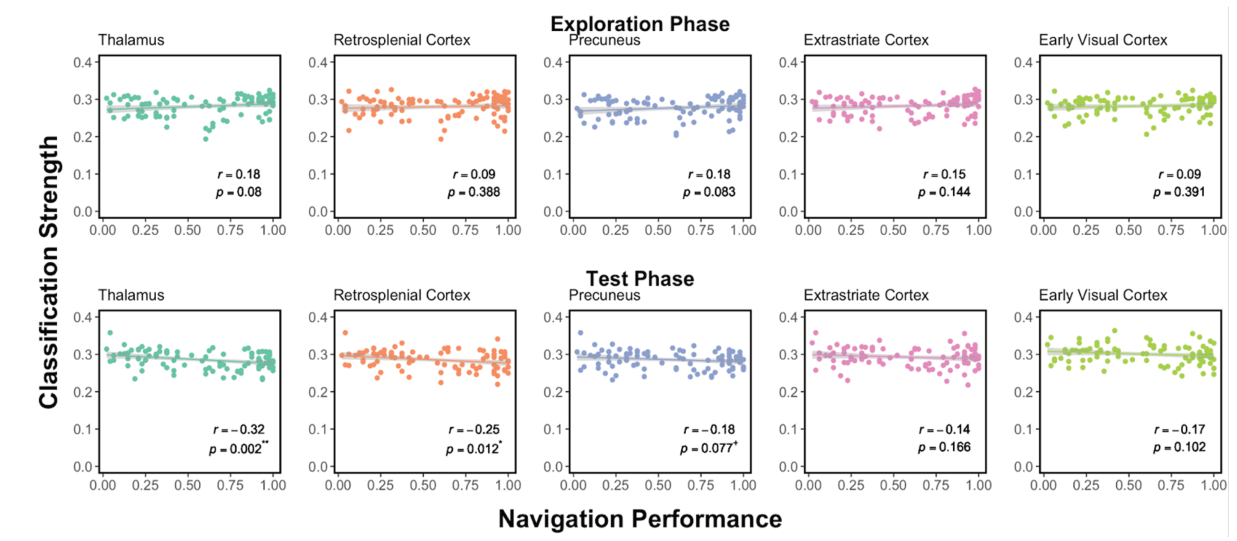
Results

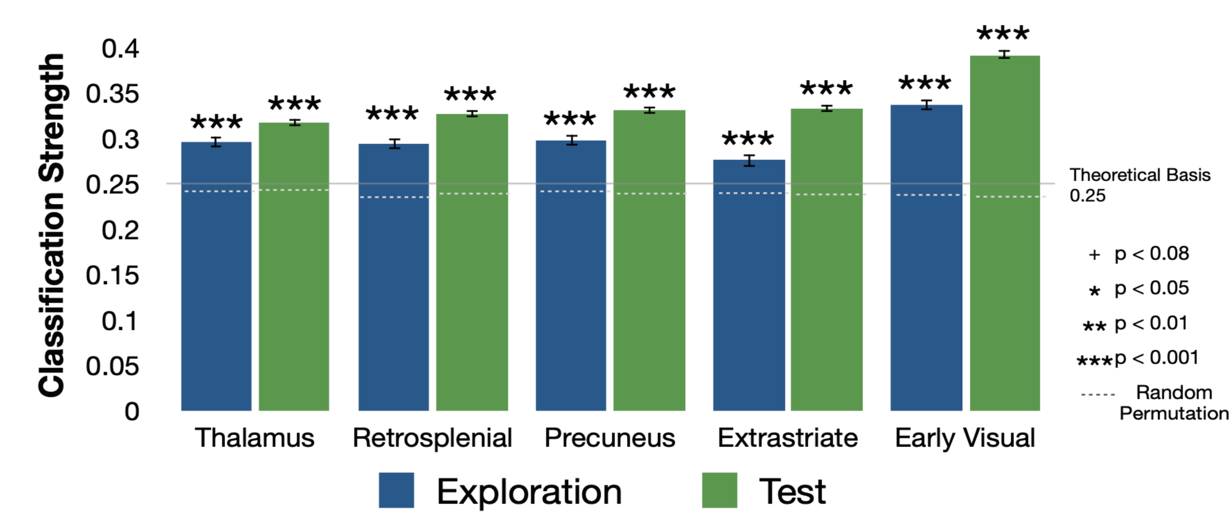
Stationary Decision-Making Period

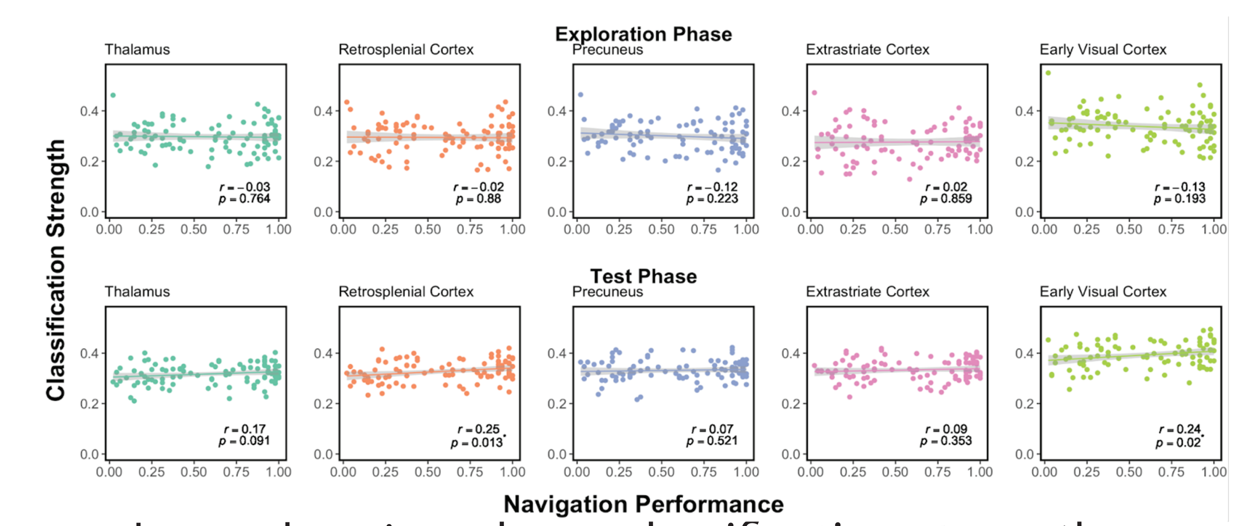




- In the exploration phase, signals could be classified in thalamus, retrosplenial cortex, and early visual cortex
- In the test phase, signals could only be classified in early visual cortex
- In the exploration phase, classification strength was positively correlated with navigation performance (none reached significance)
- In the test phase, classification strength was negatively correlated with navigation performance (thalamus and retrosplenial cortex reached significance)

Translational Movement Period





- In the exploration phase, signals could be classified in all 5 regions of interest
- In the test phase, signals could be classified in all 5 regions of interest
- In the exploration phase, classification strength was negatively correlated with navigation performance except in extrastriate cortex (none reached significance)
- In the test phase, classification strength was positively correlated with navigation performance (retrosplenial cortex and early visual cortex reached significance)

Conclusions

- We are able to classify the basic navigational signal of head direction within the neural circuitry of humans in both the stationary decision-making period and the translational movement period
- The classification strengths of head direction signals were stronger in downstream areas of early visual cortex in translational movement than in stationary decision-making possibly due to the contribution of MT and MST cells in visual cortex during movement
- Translational movement period could reveal a mixture of signals from head direction system and travel direction system

References

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