Navigational Agency Modulates Neural Representations of Spatial Environments

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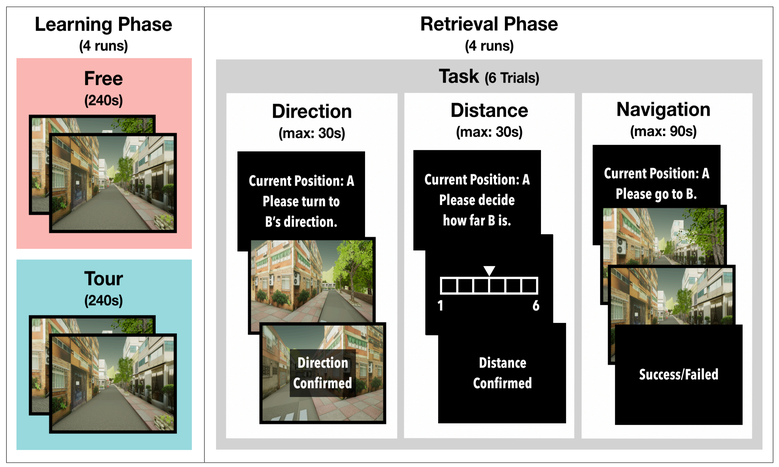
Introduction

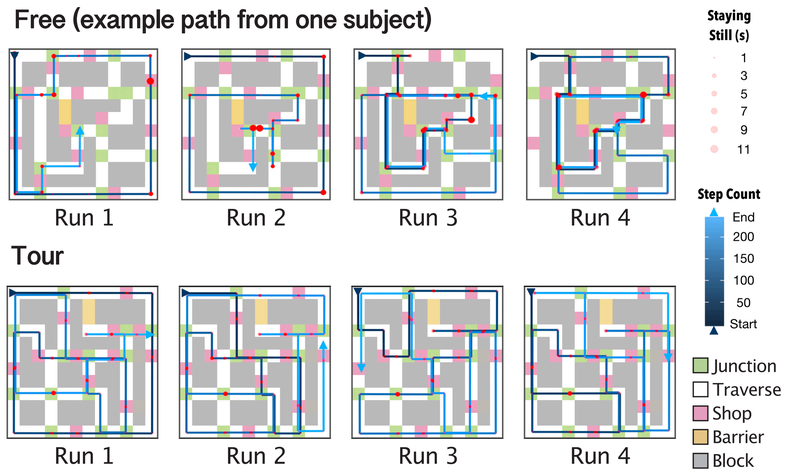
- **Spatial navigation (SN)** involves forming accurate neural representations of the environment[1] usually with movement actions that involve making navigational decisions[2].
- However, how navigational agency in SN modulates neural spatial representations remains unclear.
- We evaluated the effects of navigational **decision making (DM)** on SN-related neural responses under conditions of internally (Free) vs. externally (Tour) generated navigational steps.

Methods

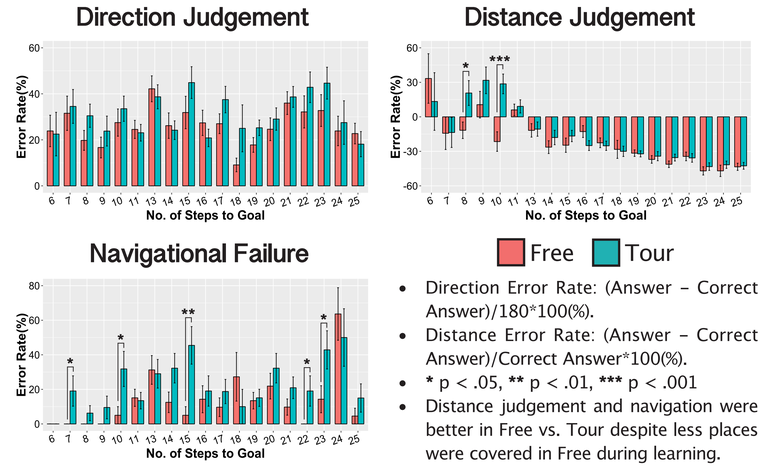
- 21 Participants: 23.7±2.3 yrs old, 11 females.
- **SN Task**: Participants underwent SN both with and without DM in an fMRI design task, and were required to learn and later retrieve the locations of 12 goals in a virtual map.
  - **Learning Phase**:Under SN with DM **(Free),** participants were allowed to navigate freely, while under SN without DM **(Tour)**, only guide videos were presented.
  - **Retrieval Phase**: Participants were asked to point out the goal's **direction**, **distance**, and **navigate** to the goal.
- 2 Virtual Mazes: Each maze consistutes 12 **goal shops**, 13 **junctions**, 3 barriers, 47 blocks, and number of steps to goal from 6 to 25.
- 8 EPI Runs: voxel size 2.8x2.8x3 mm, FOV = 220x220 mm, 38 axial slices, matrix size 78x78, TR = 2.4 s.



Different Learning Pattern in Free vs. Tour

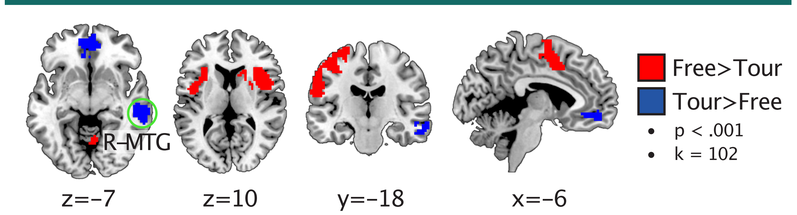


Overall Better Performance in Free vs. Tour



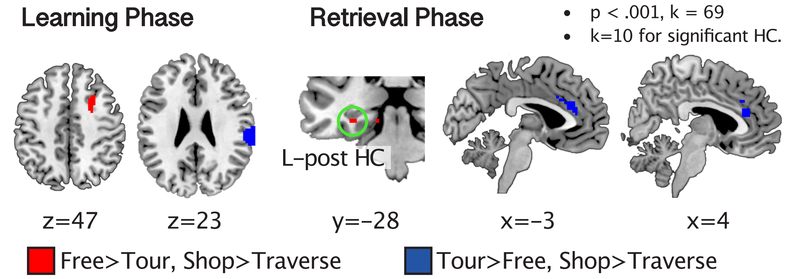
- Direction Error Rate: (Answer − Correct Answer)/180*100(%).
- Distance Error Rate: (Answer − Correct Answer)/Correct Answer*100(%).
- * p < .05, ** p < .01, *** p < .001
- Distance judgement and navigation were better in Free vs. Tour despite less places were covered in Free during learning.

Distinct Neural Response During Learning in Free vs. Tour



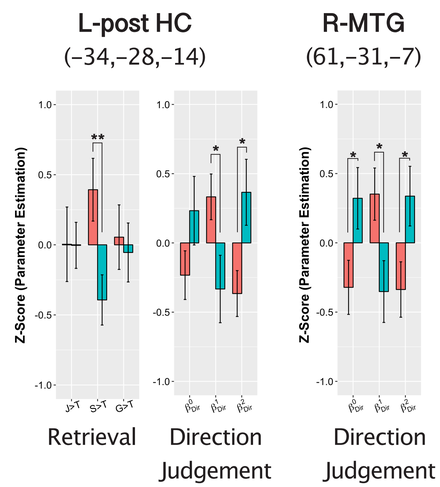
- p < .001
- k = 102

Distinct Neural Response Between Passing Shops vs. Traverses in Free vs. Tour



- p < .001, k = 69
- k=10 for significant HC.

Brain Regions Sensitive to Direction Judgement Modulated by Distance in Free vs. Tour



- J : Junction
- T : Traverse
- S : Shop
- G : Goal
- β^0_{Dir}: Direction judgement modulated by 0th order goal-to-goal distances.
- β^1_{Dir}: Direction judgement modulated by 1st order goal-to-goal distances.
- β^2_{Dir}: Direction judgement modulated by 2nd order goal-to-goal distances.
- * p < .05, ** p < .01, *** p < .001
- Distinct neural responses between Free vs. Tour are found during direction judgement despite no behavioral differences during this period.

Conclusion

- Navigational DM, manipulated as internally generated navigational steps (Free), enhances agency in SN, and involves forming more accurate spatial representations with overall better performances.
- Neural responses revealed distinct spatial representations while passing different landmarks in the map during both learning and retrieval between SN with and without DM.
- Our findings showed that DM altered hippocampal and temporal processing of spatial distances during access to map locations.

Reference

[1]Bowman, D. A., Davis, E. T., Hodges, L. F., & Badre, A. N. (1999). Maintaining spatial orientation during travel in an immersive virtual environment. Presence, 8(6), 618-631.

[2]Chrastil, E. R., & Warren, W. H. (2013). Active and passive spatial learning in human navigation: Acquisition of survey knowledge. Journal of experimental psychology: learning, memory, and cognition, 39(5), 1520.

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