The relationship between hippocampal subfield volumes and individual differences in navigation ability

Alina S. Tu, Nicholas Krohn, Olivia Cooper, Caitlin McIntrye, Elizabeth R. Chrastil

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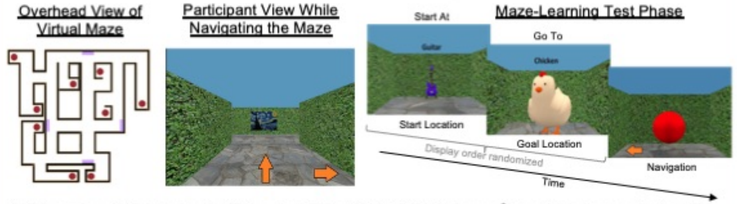
BACKGROUND

- Hippocampal (HC) volumes correlate with navigation ability in extreme populations[1]
  - Correlations between HC volumes and navigation performance in the healthy, young adult population are only observed in small samples[2-4]
- HC *subfields* individually relate to various aspects of memory
  - Cornu Ammonis 3 (**CA3**) and dentate gyrus (**DG**) volumes correlate with pattern separation[5] and memory ability[6]
  - **CA1** volumes relate to verbal memory recall ability[6]
- Other medial temporal lobe (MTL) regions are important for successful navigation
  - Entorhinal cortex (**ERC**)'s grid cells fire as animals navigate space[7]
  - **ERC** volume loss relates to poorer spatial memory[8]
- **Hypotheses**:
  - If pattern separation ability is necessary for successful maze navigation, **CA3** and **DG** volumes are associated with navigation ability in maze
  - Otherwise, **CA1** and **ERC** volumes are related to navigation performance due to participants' reliance on spatial memory for successful navigation

METHODS

- 28 participants with high-resolution T2 MRI scans, 2 excluded
  - 26 participants in final analysis (13 females, M_{age} = 21.96, SD_{age} = 4.43)
- **Maze-Learning Task**: Learn locations of 9 target objects
  - Maze accuracy = # of correct trials divided by total # of trials completed
  - Path efficiency = distance of path taken divided by shortest possible distance



- **MRI scans**: Whole-brain T1w and T2w (0.9×0.9×0.9 mm^3) and high-resolution T2 (0.4×0.4×0.2 mm^3)
  - Image processing: Automatic Segmentation of Hippocampal Subfields (ASHS)[9] software pipeline automatically segmented MTL to 7 subfields per hemisphere
    - Manual clean-up and segmentation on ITK-SNAP
  - Obtained 14 subfield volume and thickness (volume divided by subfield length) values per participant

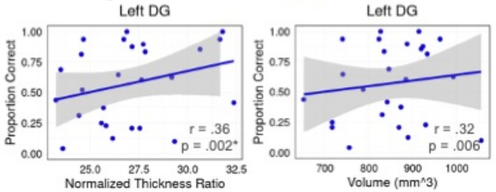
MAIN RESULTS

With sex, age, and total intracranial volume as covariates in all correlation analyses, we conducted partial correlations between 2 measures of navigation ability:

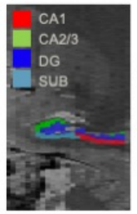
With Manual ASHS Clean-Up:

Maze accuracy and…

1. Each of the 4 HC subfield *volumes* and *thicknesses* due to premature posterior cut-offs in 12 high-resolution T2 scans, affecting ERC, PRC, PHC
   - Bonferroni-corrected p < .0036, n = 25
   - **Significant** correlation with left **DG** thickness
   - Trending correlation with left **DG** volume

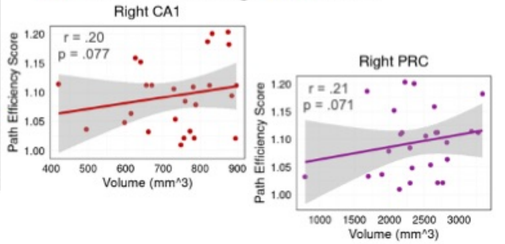


HC Subfields in Sagittal View



Path efficiency and…

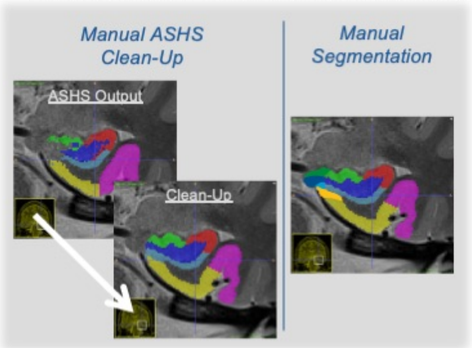
1. Each of the 4 HC subfield *volumes* and *thicknesses*
   - Bonferroni-corrected p < .0036, n = 25
   - **No significant** but trending correlations with right **CA1** volume and with right **PRC** volume



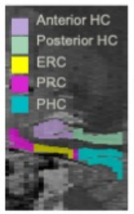
With Manual Segmentation:

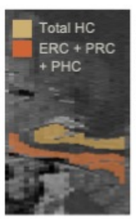
Maze accuracy and…

2. Each of the 5 MTL subfield *volumes* and *thicknesses*
   - Bonferroni-corrected p < .005, n = 26
   - **No significant** correlations
3. Total HC and total MTL *volumes*
   - **No significant** correlations, n = 26
   - Consistent with recent findings from this population[3-4]



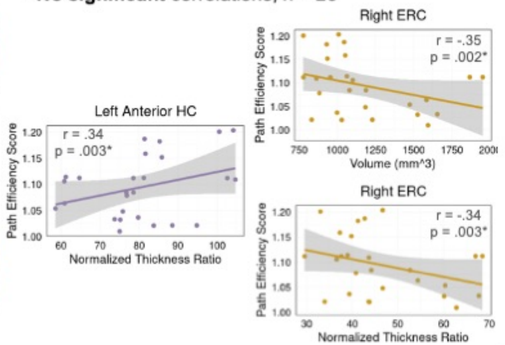
MTL Regions in Sagittal View





Path efficiency and…

2. Each of the 5 MTL subfield *volumes* and *thicknesses*
   - Bonferroni-corrected p < .005, n = 26
   - **Significant** correlations with right **ERC** volume, with left anterior HC thickness, and with right **ERC** thickness
3. Total HC and total MTL *volumes*
   - **No significant** correlations, n = 26



DISCUSSION

- Overall, current results suggest that navigation abilities in healthy, young adult population relate to certain hippocampal *subfield* volumes
  - Specifically, larger left **DG** subfield volume and thickness are correlated with more accurate navigation, likely due to its role in pattern separation and memory recall
  - Larger **ERC** volume and thickness are both associated with better path efficiency, likely due to its involvement in computing metric distances in the environment as part of path integration[10]
- Limitations include:
  - Posterior cut-offs in some high-resolution scans
  - Methodological differences (i.e. ASHS vs. manual segmentation, lack of a single segmentation protocol)
- We aim to expand this analysis to include the full data set (>100 participants) and analyze the relationship between subfield volumes and other aspects of navigation ability
  - e.g. Santa Barbara Sense of Direction Scale, Spatial Orientation Task, Video Game Experience
- These findings can help inform the ongoing debate about the relationship between hippocampal volume and navigation ability

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UCI BioSci | Department of Neurobiology and Behavior

UCI CNLM Ayala School of Biological Sciences | Center for the Neurobiology of Learning & Memory

@alinatu0
alinat2@uci.edu