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# Spatial Cognition

March 6th, 2025

Presenter: Tzu-Yen, Yang



# Agenda

- Spatial Cognition
  - Self-localisation
    - Reference frames
  - Navigation
  - Spatial cognition develops with age and experiences



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# Reminders & Announcements

## 1. Optional quiz 3 this Friday

**PUBLIC EVENTS WITH PROF. FRITZ BREITHAUP**  
(PROVOST PROFESSOR OF GERMANIC STUDIES AND COGNITIVE SCIENCE; FOUNDER OF THE "EXPERIMENTAL HUMANITIES LAB," INDIANA UNIVERSITY) AT CORNELL UNIVERSITY, MARCH 10-12, 2025



**Panel Discussion**  
Monday, March 10, 5 pm, 700 Clark Hall  
"What is a Humanities Lab? From Literature to AI"  
With Fritz Breithaupt and Laurent Guirel (Professor of French, Francophone & Comparative Literature and of Cognitive Science, founder of the "Humanities Lab," Cornell University); moderated by Durka Shosh (Director of the Society for the Humanities; Professor of History, Asian Studies, Feminist, Gender and Sexuality Studies, Cornell University)

**University Lecture**  
Tuesday, March 11, 4 pm, A.D. White House  
"The Narrative Brain"

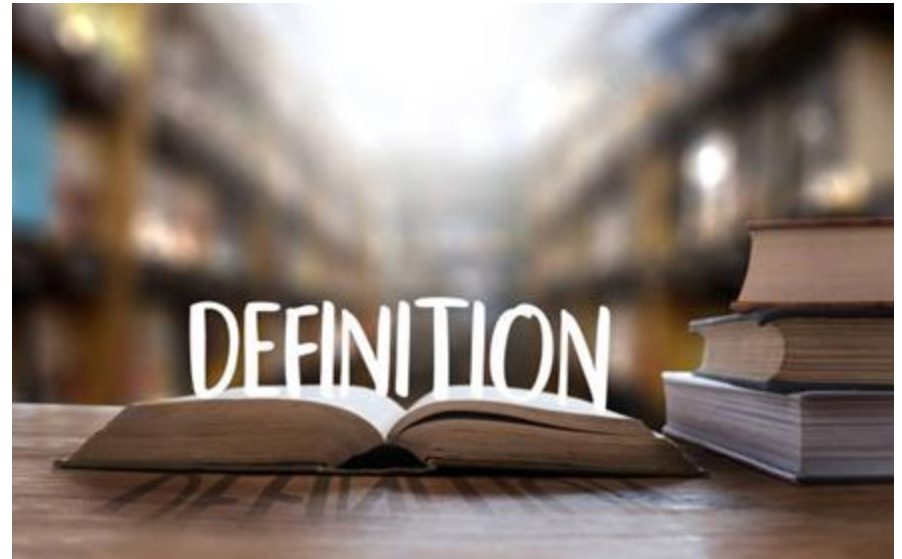
**Lunch with Students**  
Wednesday, March 12, 12-1:30 pm, 193 Gehlen Smith  
Drop by anytime

The Department for German Studies & the Institute for German Cultural Studies and the University Language Committee, with the support of the Departments of Brain Studies, Comparative Literature, History, Linguistics, Literature in English, Music, Philosophy, Religious Studies, the Cognitive Science Program, the French Studies Program, the Society for the Humanities and the Humanities Lab at Cornell University.



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# Spatial Cognition





## Spatial Cognition

- The use of internal knowledge about the layout of the world and the body's relationship to it in order to organise spatial actions like reaching, **self-localisation** and **navigation**.



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# How is Spatial Location Represented?





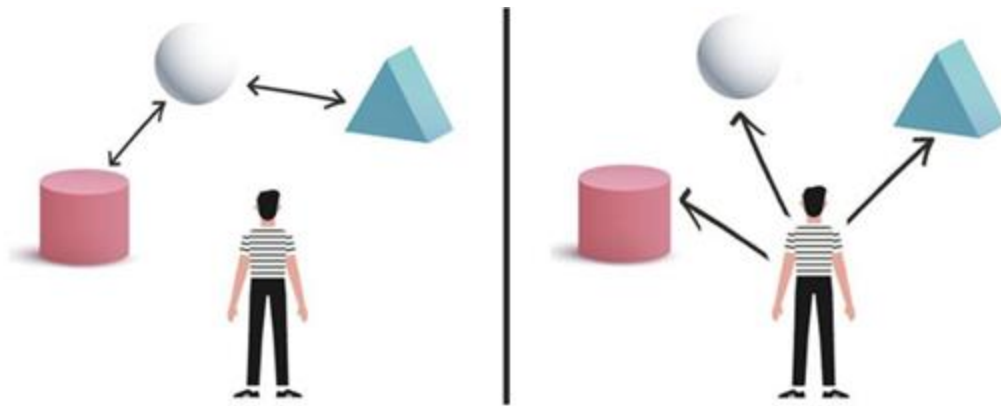
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# How is Spatial Location Represented?





## How is Spatial Location Represented?



Mirino, et al. (2022).

Allocentric: Spatial information based on the navigator's perception of relative landmark positions (left).

Egocentric: Bases spatial representations from the point of view of the navigator (right)

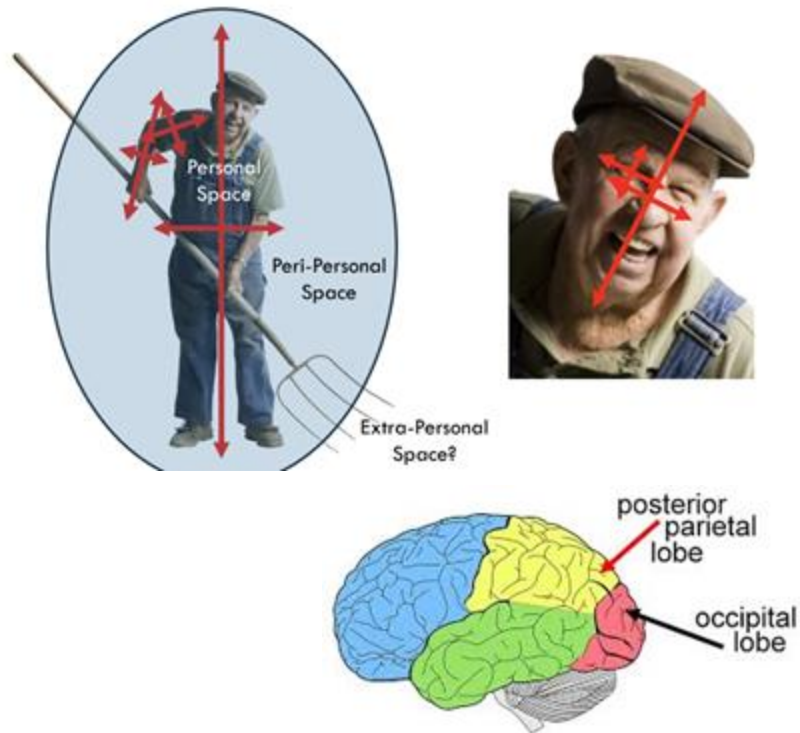




# How is Spatial Location Represented?

## Egocentric Reference Frames

- Relative to self
  - Body-centered
  - Limb-centered
  - Head-centered
  - Eye-centered
- Relevant for
  - personal space
  - peri-personal space
- Posterior parietal lobe



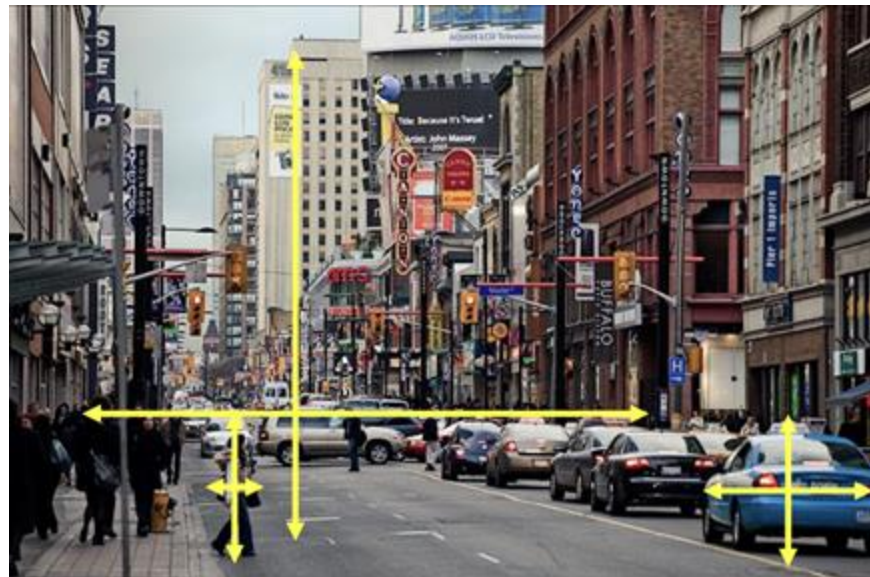
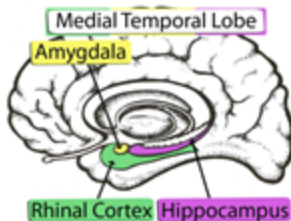


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# How is Spatial Location Represented?

## Allocentric Reference Frames

- Centered on
  - Environment
  - Objects
- Both peri- and extra-personal space
- Medial temporal lobe





# Egocentric Reference Frames

## - Taylor Swift - **ME!**

I promise that you'll never find another like **me**  
I know that I'm a handful, baby, uh  
I know I never think before I jump  
And you're the kind of guy the ladies want  
(And there's a lot of cool chicks out there)  
I know that I went psycho on the phone  
I never leave well enough alone  
And trouble's gonna follow where I go  
(And there's a lot of cool chicks out there)  
But one of these things is not like the others

Like a rainbow with all of the colors  
Baby doll, when it comes to a lover  
I promise that you'll never find another like  
**Me-e-e**, ooh-ooh-ooh-ooh  
I'm the only one of me  
Baby, that's the fun of **me**  
Eeh-eeh-eeh, ooh-ooh-ooh-ooh  
You're the only one of you  
Baby, that's the fun of you  
And I promise that nobody's gonna love you  
like **me-e-e**  
I know I tend to make it about **me**

I know you never get just what you see  
But I will never bore you, baby  
(And there's a lot of lame guys out there)  
And when we had that fight out in the rain  
You ran after me and called **my** name  
I never wanna see you walk away  
(And there's a lot of lame guys out there)  
'Cause one of these things is not like the others  
Livin' in winter, I am your summer  
Baby doll, when it comes to a lover  
I promise that you'll never find another like  
**Me-e-e**, ooh-ooh-ooh-ooh



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# Egocentric Reference Frames

- Taylor Swift - **ME!**





## Spatial Cognition

- The use of internal knowledge about the layout of the world and the body's relationship to it in order to organise spatial actions like reaching, **self-localisation** and **navigation**.



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## Navigation

- Can be done in different ways
- Rely on different types of knowledge
- Egocentric to allocentric
- Orient self relative to world, landmarks; landmarks relative to each other

Cue



"To get to Uris Library, first walk toward the tower."

Route



"To get to Uris Hall, turn left at the intersection."

Map

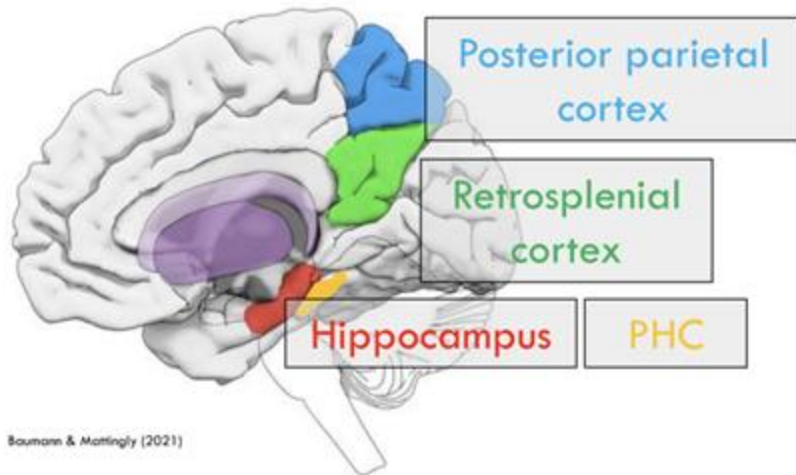


"Mann Library is east of GSH."



# Navigation

- Parietal to medial temporal lobe
  - Code multiple elements of space
  - Integrate dorsal and ventral







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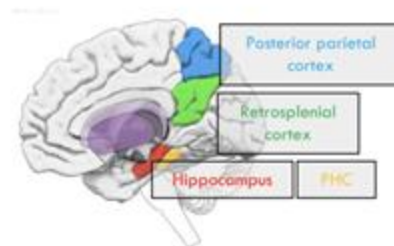
# Representing places





## Representing places

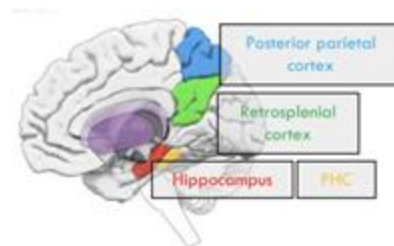
- Parahippocampal place area (PPA)
  - Represents familiar locations (“places”)





## Representing places

- Parahippocampal place area
  - Represents familiar locations (“places”)
  - Abstract: similar patterns for interior and exterior





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## Representing places

### Abstract: similar patterns for interior and exterior

The PPA doesn't just respond to specific places like rooms or buildings; it also processes places in a more abstract way. It activates similarly for both **interior** (inside) and **exterior** (outside) environments, meaning the brain recognizes different types of spaces in a similar fashion.

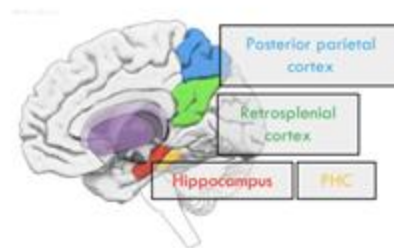
Ex. the brain might process the interior of a house and the exterior of a park in a way that is functionally similar, based on their features and familiarity, rather than focusing on the exact details of each setting.





## Representing places

- Parahippocampal place area
  - Represents familiar locations (“places”)
  - Abstract: similar patterns for interior and exterior
  - Multimodal: Auditory and visual places





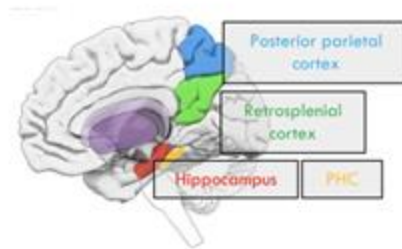
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# Allocentric Maps



## Allocentric Maps

- Hippocampus & Entorhinal cortex
- Place cells
- Head direction cells
- Combination





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# Translating Allocentric and Egocentric



## Translating Allocentric and Egocentric

- Retrosplenial cortex
- Both allocentric and egocentric
- “Route-centric”





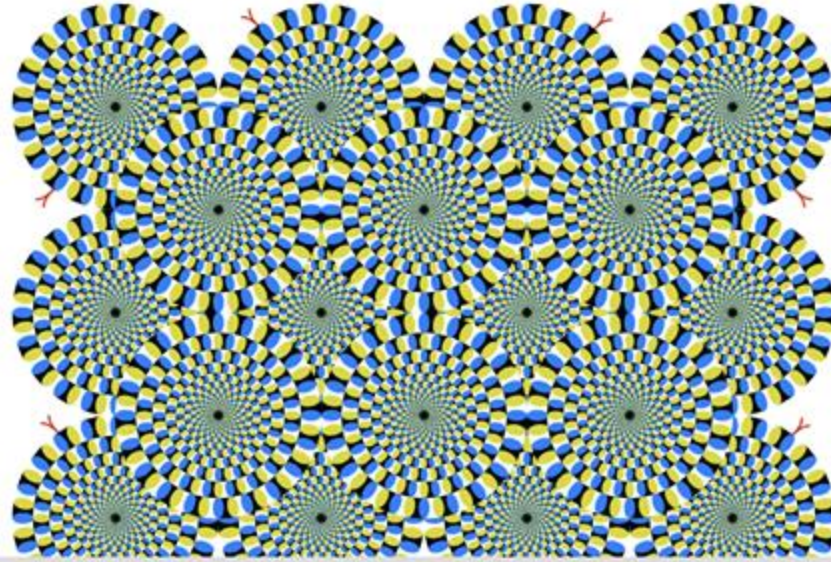
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# Eye movement



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# Your eyes typically move several times per second



Your eyes typically move several times per second

<http://www.ritsumei.ac.jp/~akitaoka/index-e.html>

<https://www.youtube.com/watch?v=CcXXQ6GCub8>



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## Eye movements complicate things

- The eyes move several times a second
- Therefore, the image on the retina changes just as often





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## Eye movements complicate things

- Where things are relative to the eyes changes
- Where the eyes are pointed changes relative to the head, body



Relative to eyes

- Baby face on right
- Baby face on left
- Kid face above

Relative to head

- Eyes pointed left
- Eyes pointed less left
- Eyes pointed right



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How can we possibly know how to act on  
visual information?



# How can we possibly know how to act on visual information?

- Challenge
  - Space & movement need to be coded relative to lots of things
  - These need to be coordinated
- Parietal cortex
  - Integrates information across modalities
  - Segregate representations for different effectors



How can we possibly know how to act on visual information?

- Eye-tracker
- Eye-tracking young children study





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## Eye tracking







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# Research in My Lab



PI  
Dr. Marianella Casasola



Dr. Aaron Beckner



David Tompkins



Tzu-Yen Yang



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## SPatial cognition And Children's Exploration (SPACE)

- Aims to document how perceptual, cognitive, motor, and language abilities relate to spatial skill development throughout infancy and childhood.
- Employs a short **eye-tracking** task, puzzle-like games, and interactive tablet play.
- Consists of 2 visits 5.5 months apart.
- Children are 24 - 42 mo at Visit 1 and are as old as 48 mo at Visit 2.





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# Eye-tracker



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# Eye-tracker: Protocol

## GIMeR (Giraffe Infant Mental Rotation)

- Children are shown a rotated giraffe between two landmarks (houses) and their mental rotation is measured from their anticipated looking to the houses.



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# Characterizing the development of mental rotation during the first few years of life



Mental rotation was measured based on children's ability to execute an eye movement to a landmark based on the face-direction of a cartoon giraffe





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Children would progress through angles based on their accuracy matching the giraffe to the house



15°



30°



45°



60°

...



180°

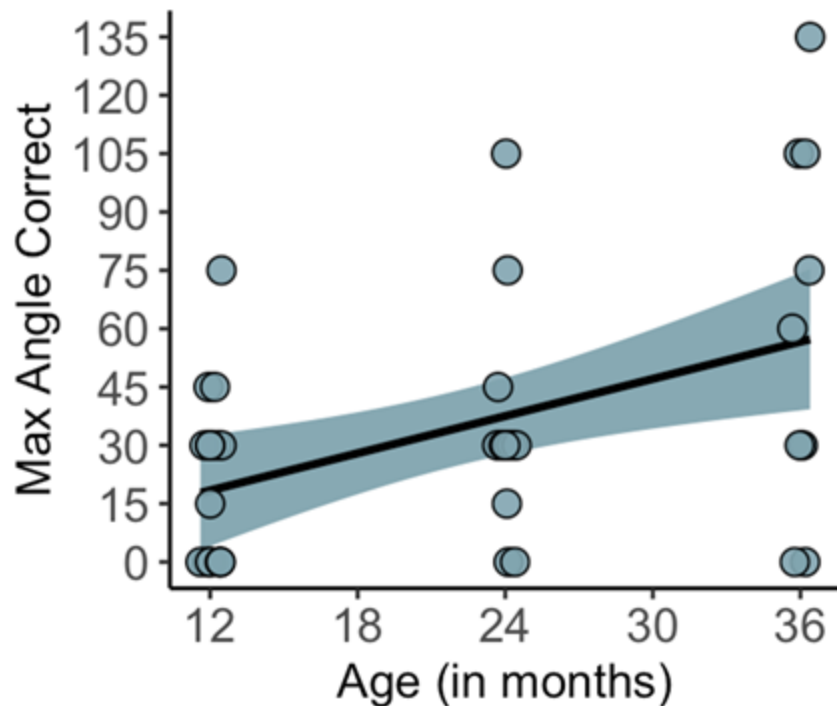
This repeated until a max angle correct, or threshold, is obtained



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# Results



12 months



24 months



36 months



Beckner, Katz, et al. (2023)





## Conclusions

- Children show evidence of mental rotation as early as 12 months
- Older children's mental rotation ability is better than younger children

Beckner, Katz, et al. (2023)



## Recap

- Spatial Cognition
  - Self-localisation
    - Reference frames
  - Navigation
  - Spatial cognition develops with age and experiences



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# Questions?





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THANK YOU!