

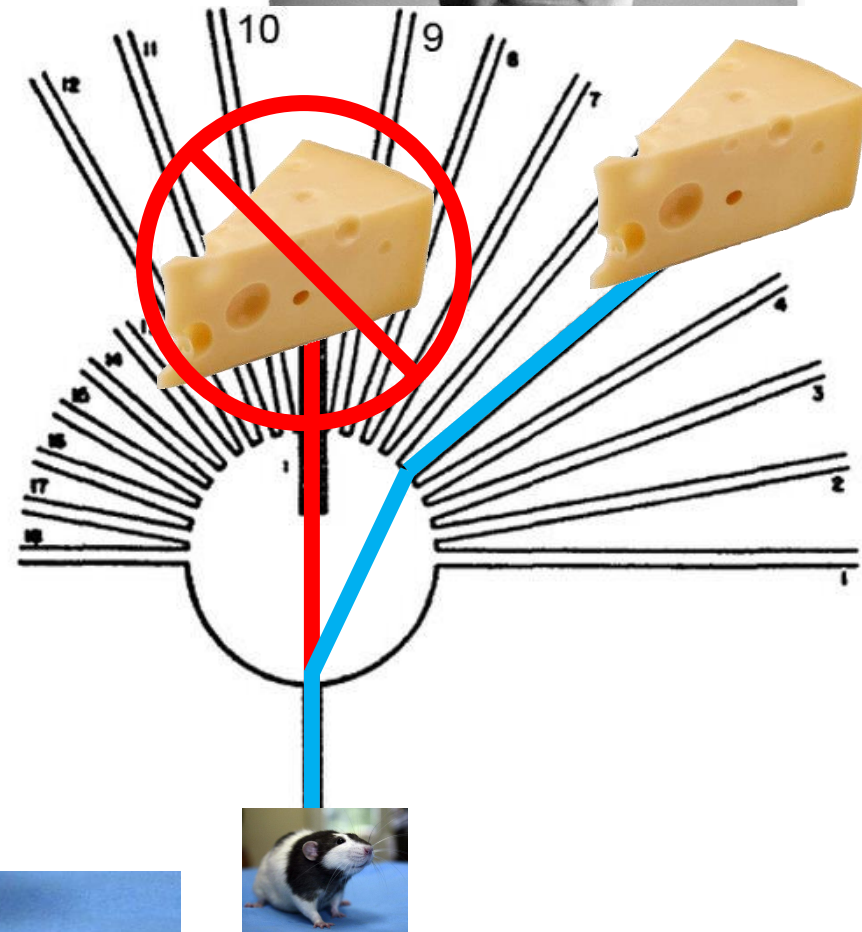
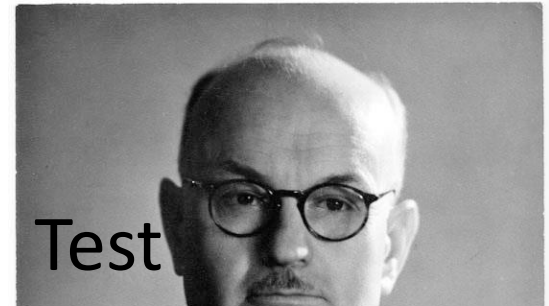
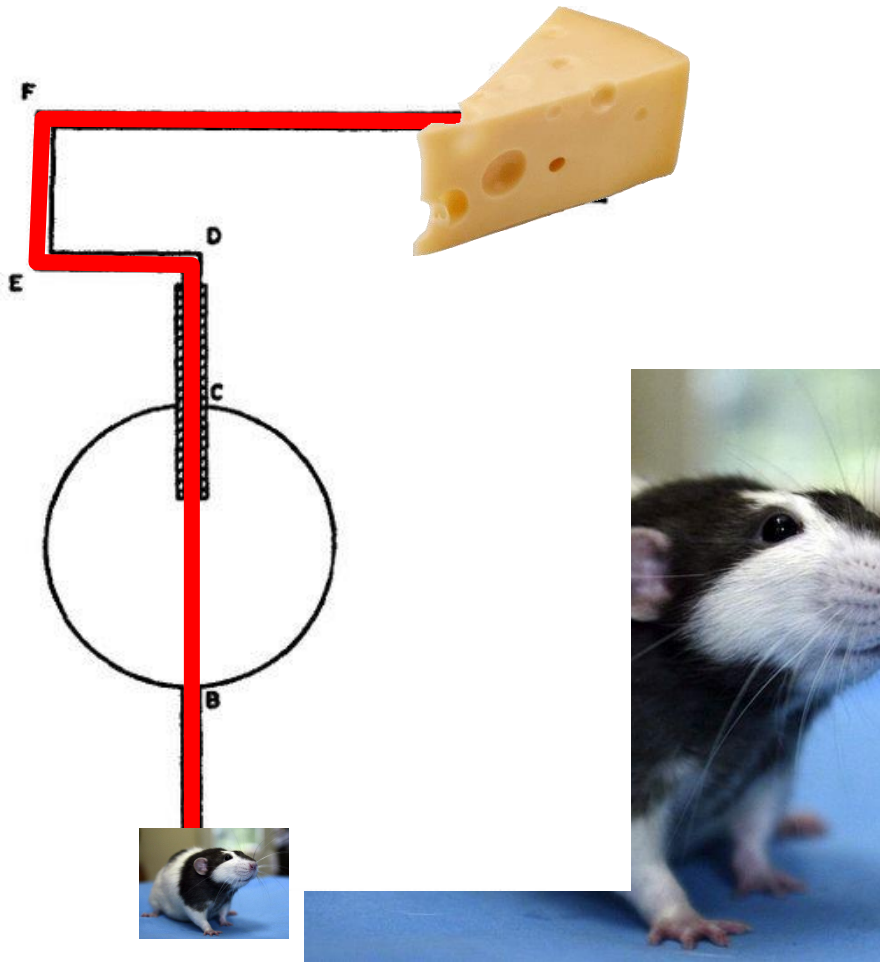
Head space: Neural and behavioral principles of spatial navigation

Steven M. Weisberg • 2/12/2019 • The University of Florida



The cognitive map

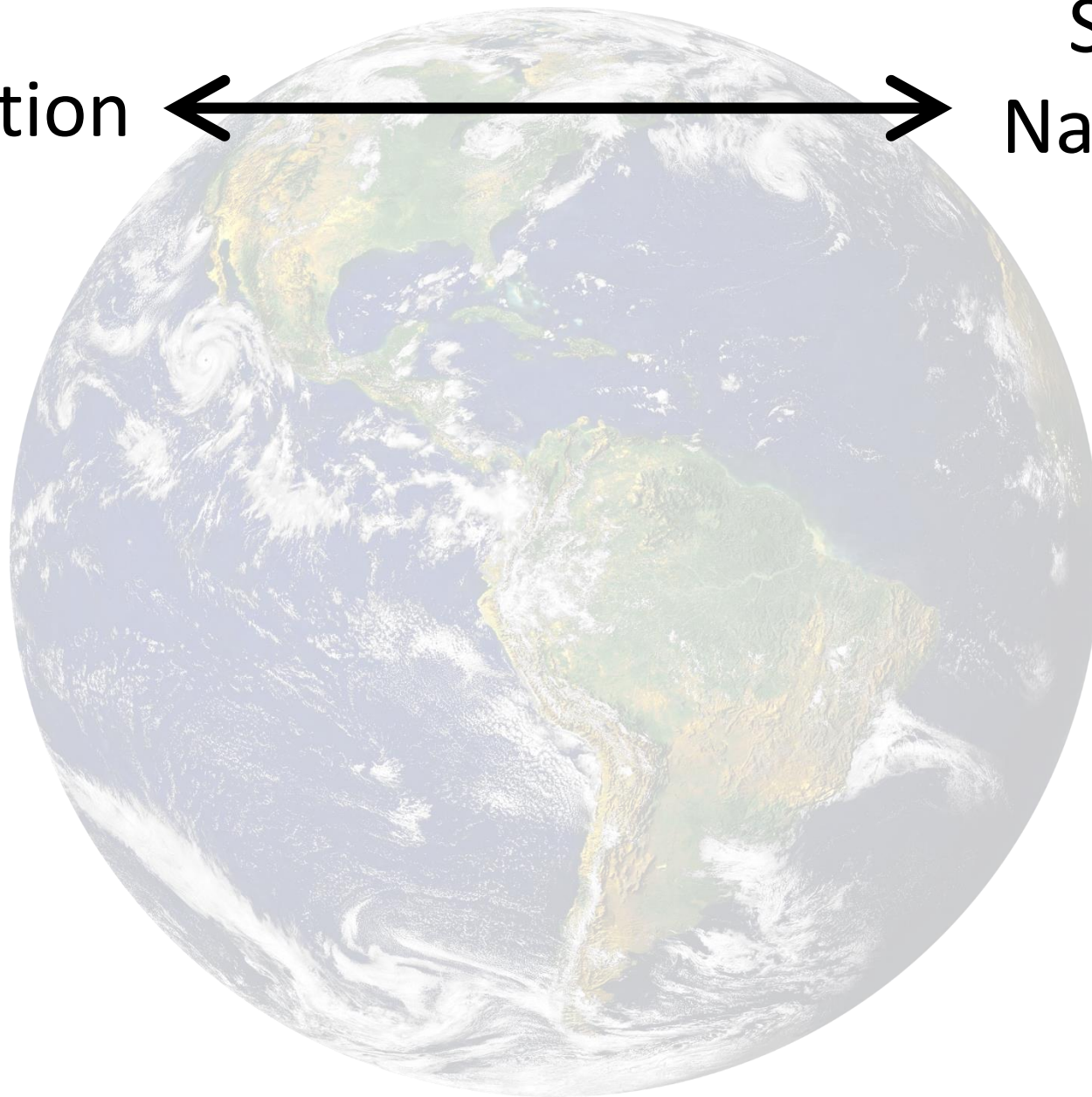
Training



Tolman (1948)



Cognition



Spatial
Navigation

Attention

Sensory
Integration

Spatial
Navigation

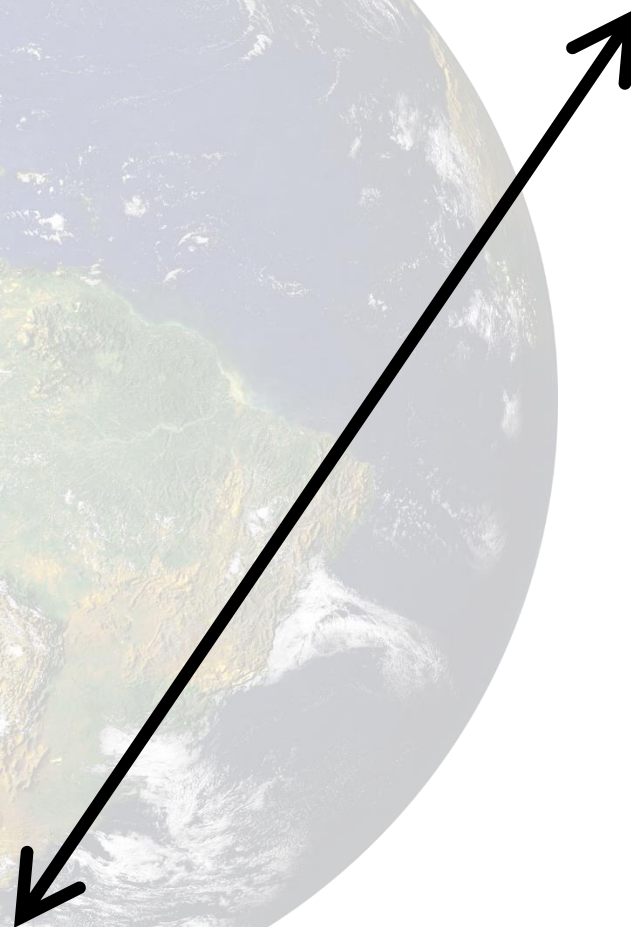
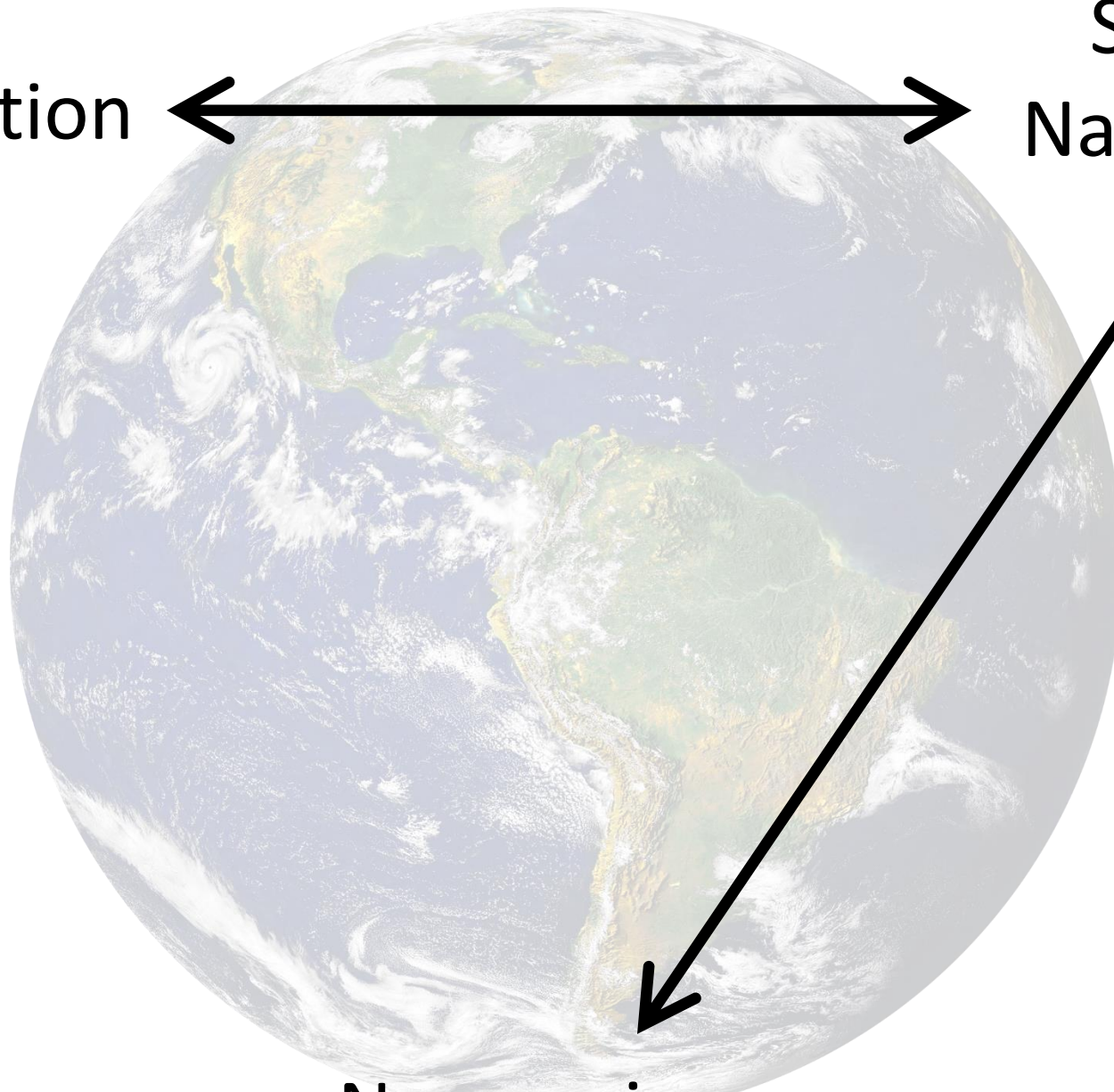
Memory

Representation

Cognition



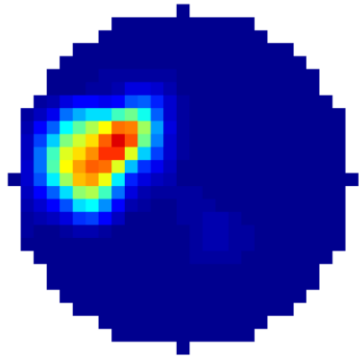
Spatial
Navigation



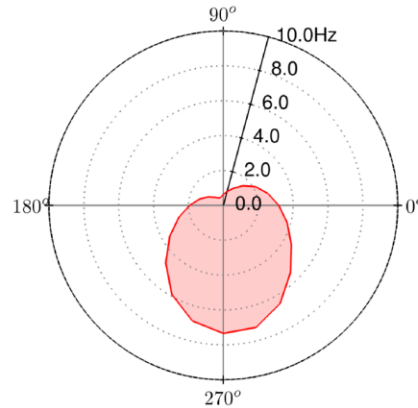
Neuroscience

The *neural* map

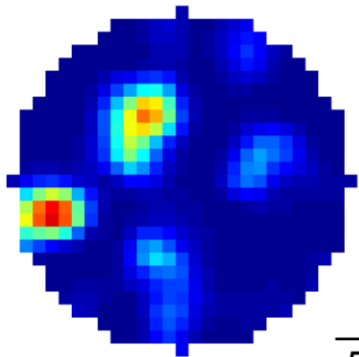
Place Cell



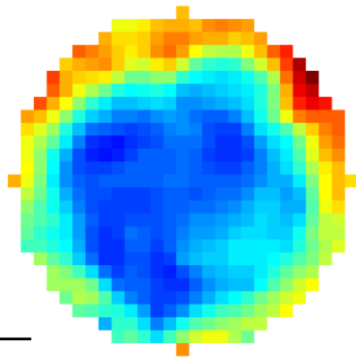
Head Direction Cell



Grid Cell



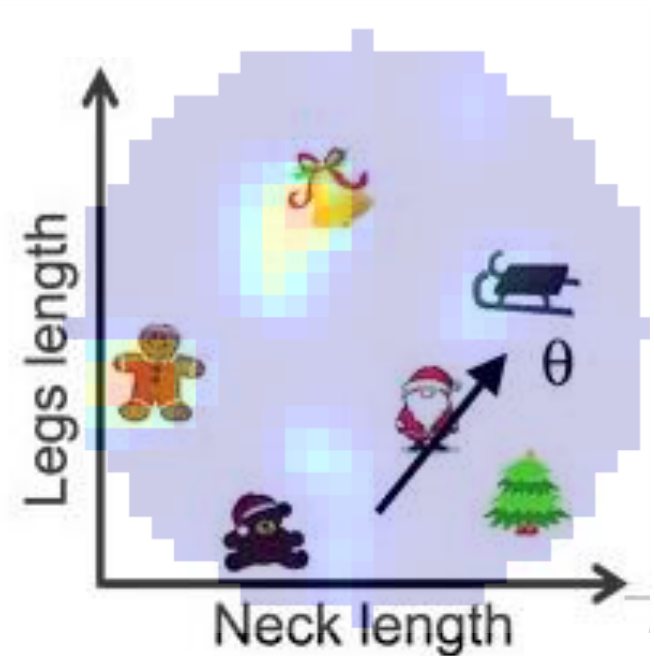
Border Cell



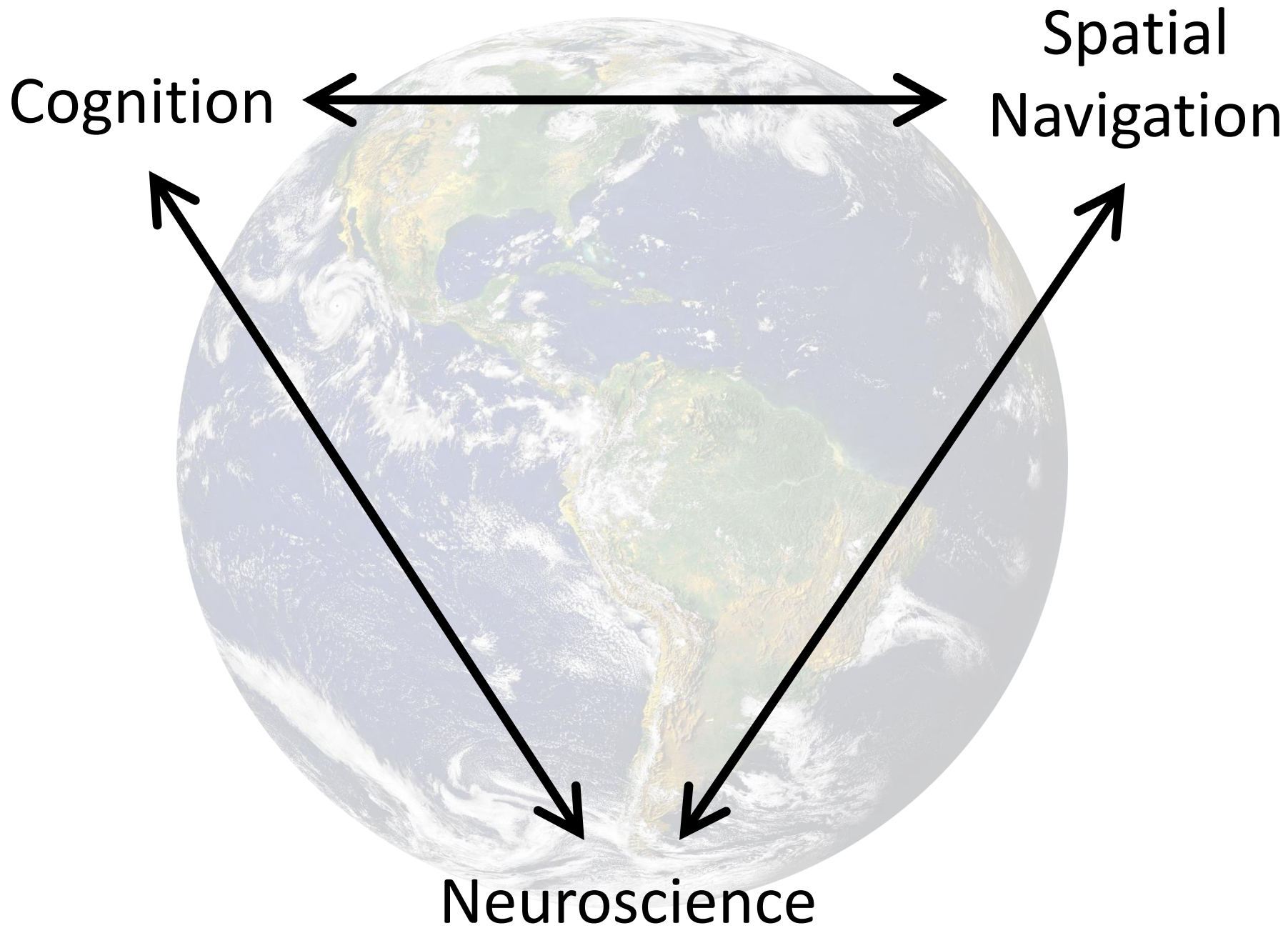
50 cm



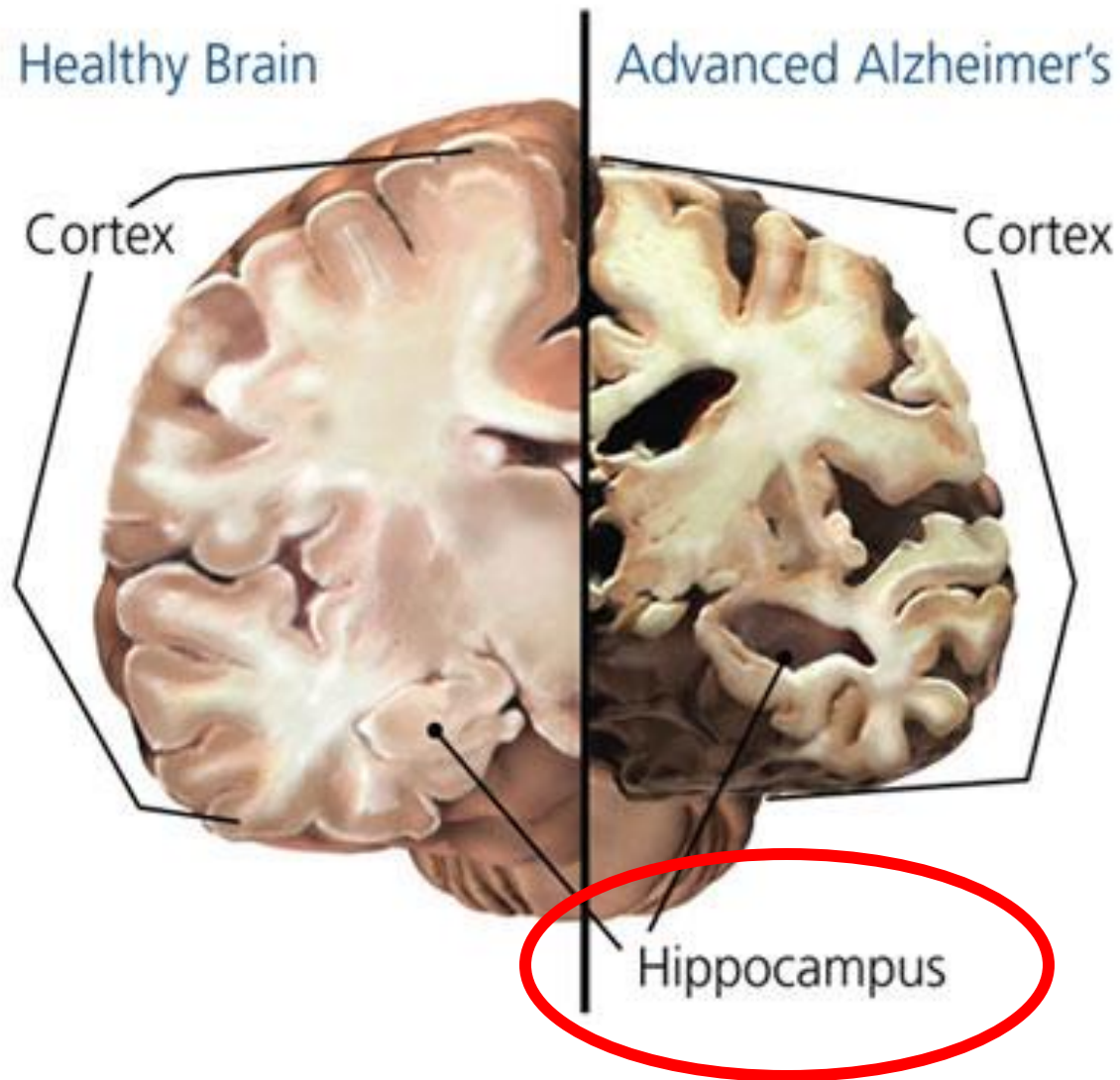
O'Keefe & Nadel (1978); Hafting et al. (2005); Taube, Muller, & Ranck (1990); O'Keefe & Burgess (1996)

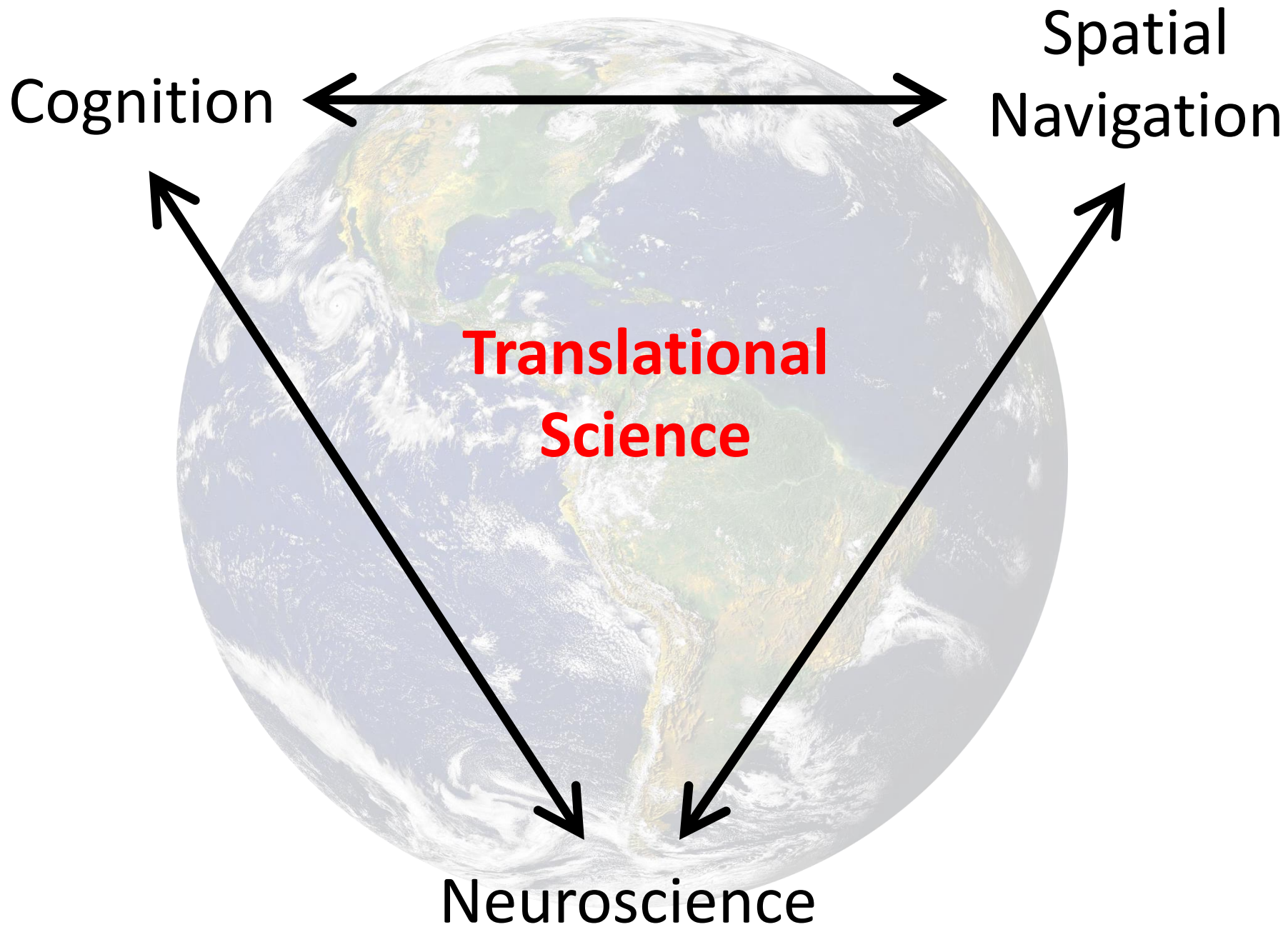


Constantinescu et al. (2016)

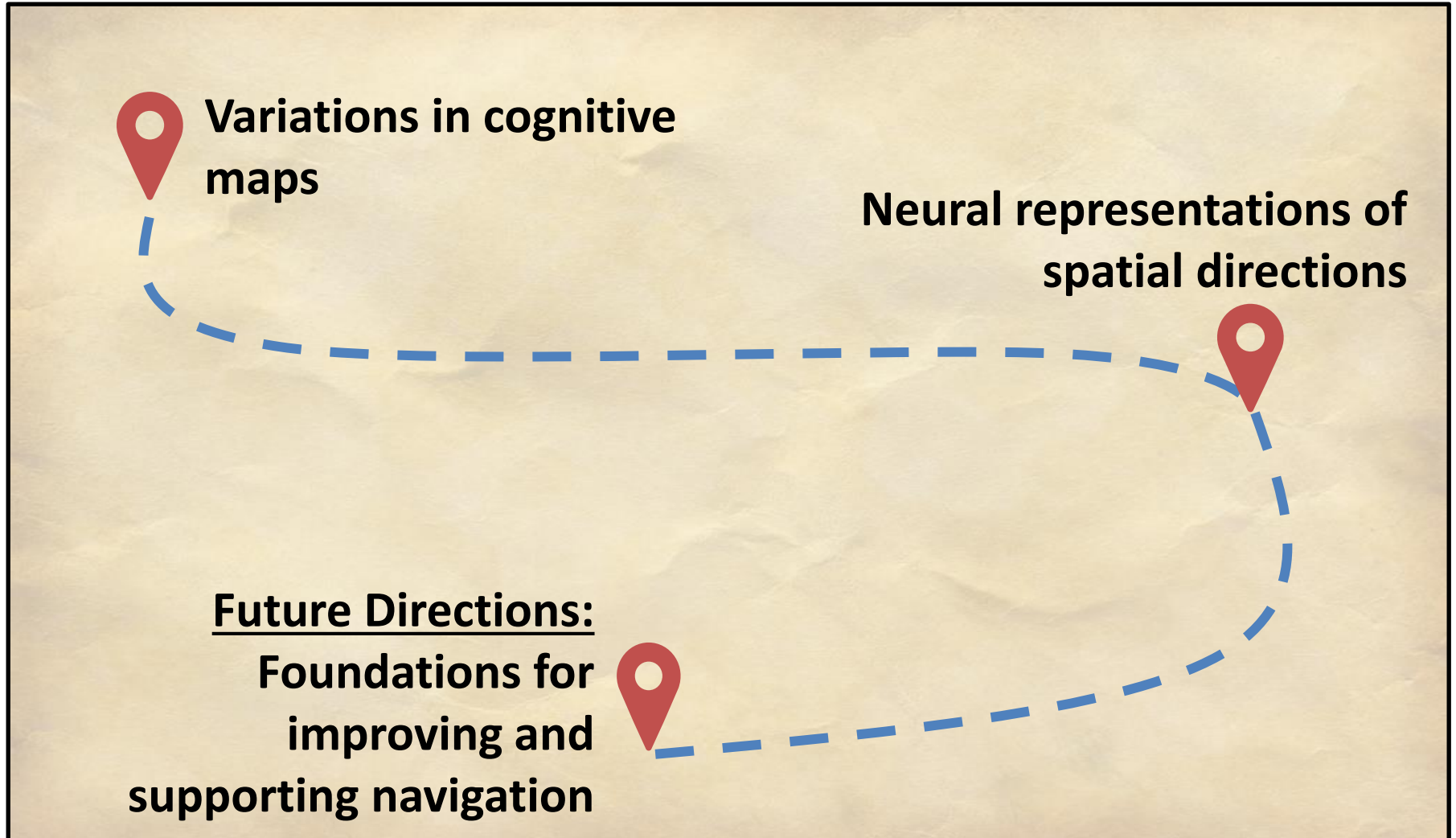


The *neurological* map

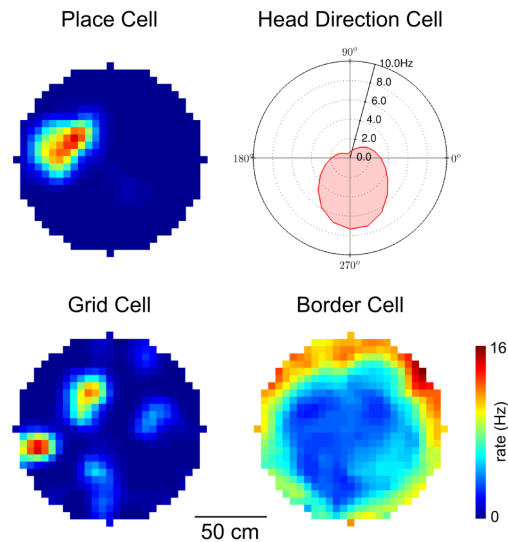




Our Road Map



How do people construct large-scale spatial representations?



Temple Christian School Campus



Weisberg & Newcomb (2016) JE (2018)

Online Data Collection & Repository

Virtual SILCton


Participants

Please select the lab you are participating through:

- [Temple Lab](#)
- [Chicago Lab](#)
- [University of Cyprus](#)
- [ETH](#)
- [Spiers Lab](#)
- [Chein Lab](#)

Experimenters

Manage Your Studies

 a site by **Strategic Spatial Solutions, Inc.**

Virtual SILCton Experimenter InterfaceSteve Weisberg ▾

[Labs](#) [Studies](#) [Experimenters](#) [Shared Data](#)

Browsing Data for Virtual SILCton

[Return to Study](#)

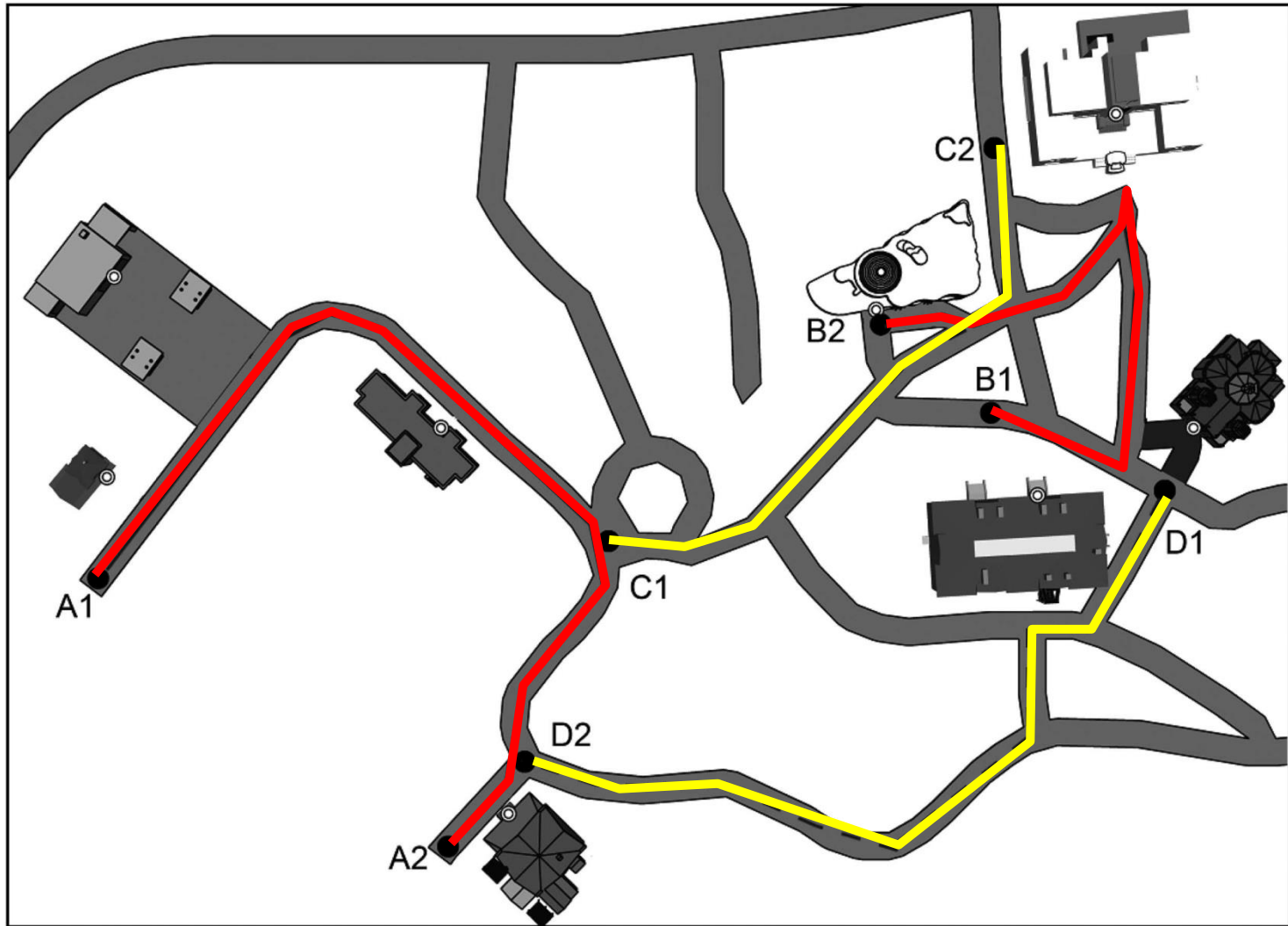
[Spatial Ability and Demographics](#) [SBSOD](#) [MRT](#) [PVAS](#) [PSAS](#) [Navigation Log](#) [Model](#) [Distance](#) [Onsite Pointing](#) [Offsite Pointing](#)

10 records per page Copy CSV Excel

participant	date	direction test	start landmark	facing landmark	target landmark	bearing	actual direction	abs error	same or different route
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Harris Hall	28	37.52863730402908	9.528637304029075	same
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Golledge Hall	9	51.76768153806619	42.7676815380662	different
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Harvey House	27	93.19423765817854	66.19423765817851	same
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Tobler Museum	32	37.308021981292235	5.308021981292256	different
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Snow Church	3	48.199475530819626	45.199475530819655	different
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Sauer Center	13	30.33169509747685	17.331695097476825	different
ART1	2011-06-06 11:45:34 -0700	0	Batty House	Lynch Station	Lynch Station	28	47.3279838915145	19.32798389151452	same
ART1	2011-06-06 11:45:34 -0700	0	Lynch Station	Harris Hall	Snow Church	72	8.968174613078455	63.03182538692155	different
ART1	2011-06-06 11:45:34 -0700	0	Lynch Station	Harris Hall	Harris Hall	23	7.021704670907995	15.978295329092006	same
ART1	2011-06-06 11:45:34 -0700	0	Lynch Station	Harris Hall	Tobler Museum	89	17.95076442063424	71.04923557936576	different

Showing 1 to 10 of 6,160 entries ← Previous 1 2 3 4 5 Next →

Virtual Silcton

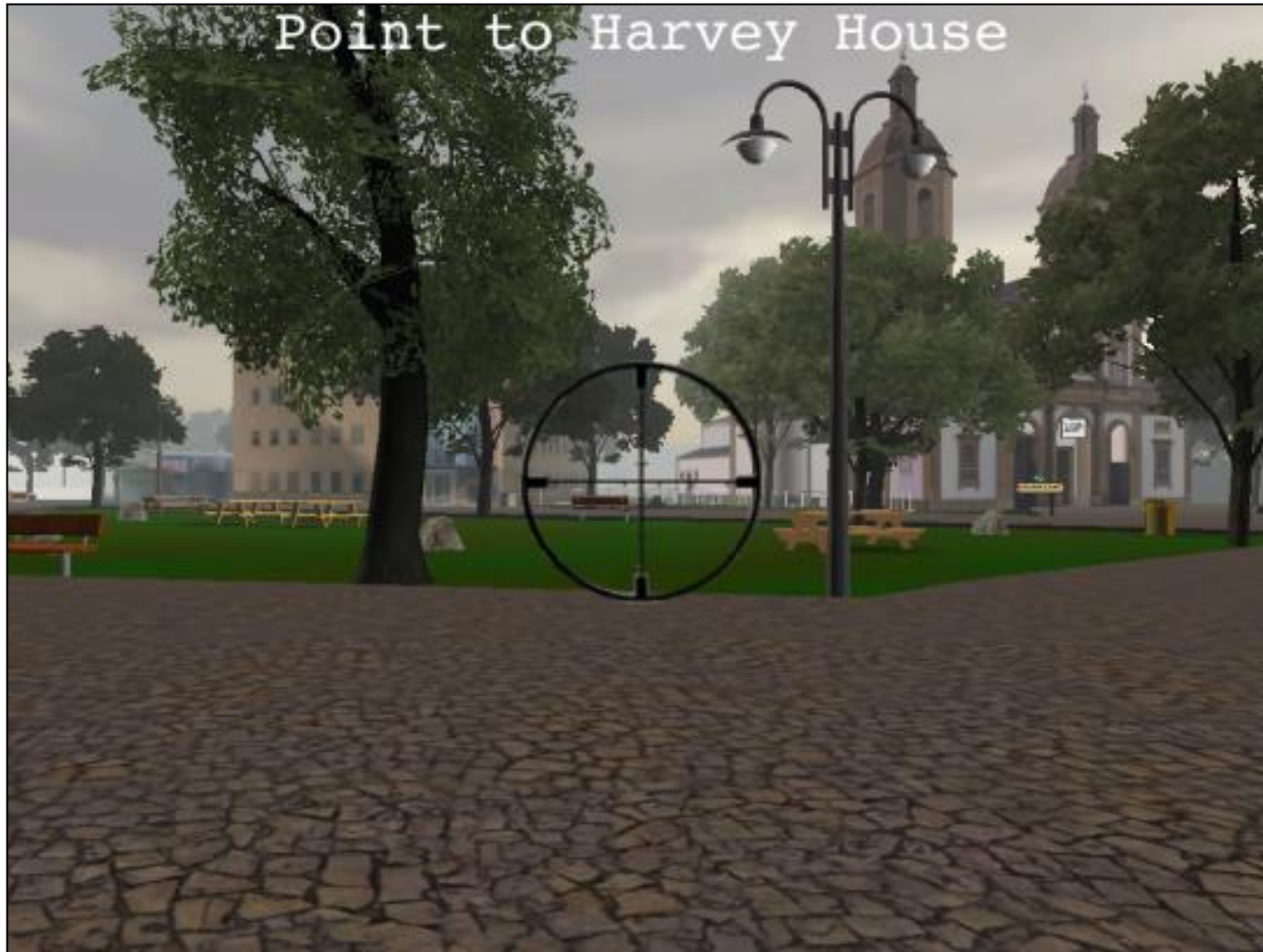


Weisberg et al. (2014) *JEP:LMC*; Weisberg & Newcombe (2016) *JEP:LMC*

Virtual Silcton (Unity 3d)

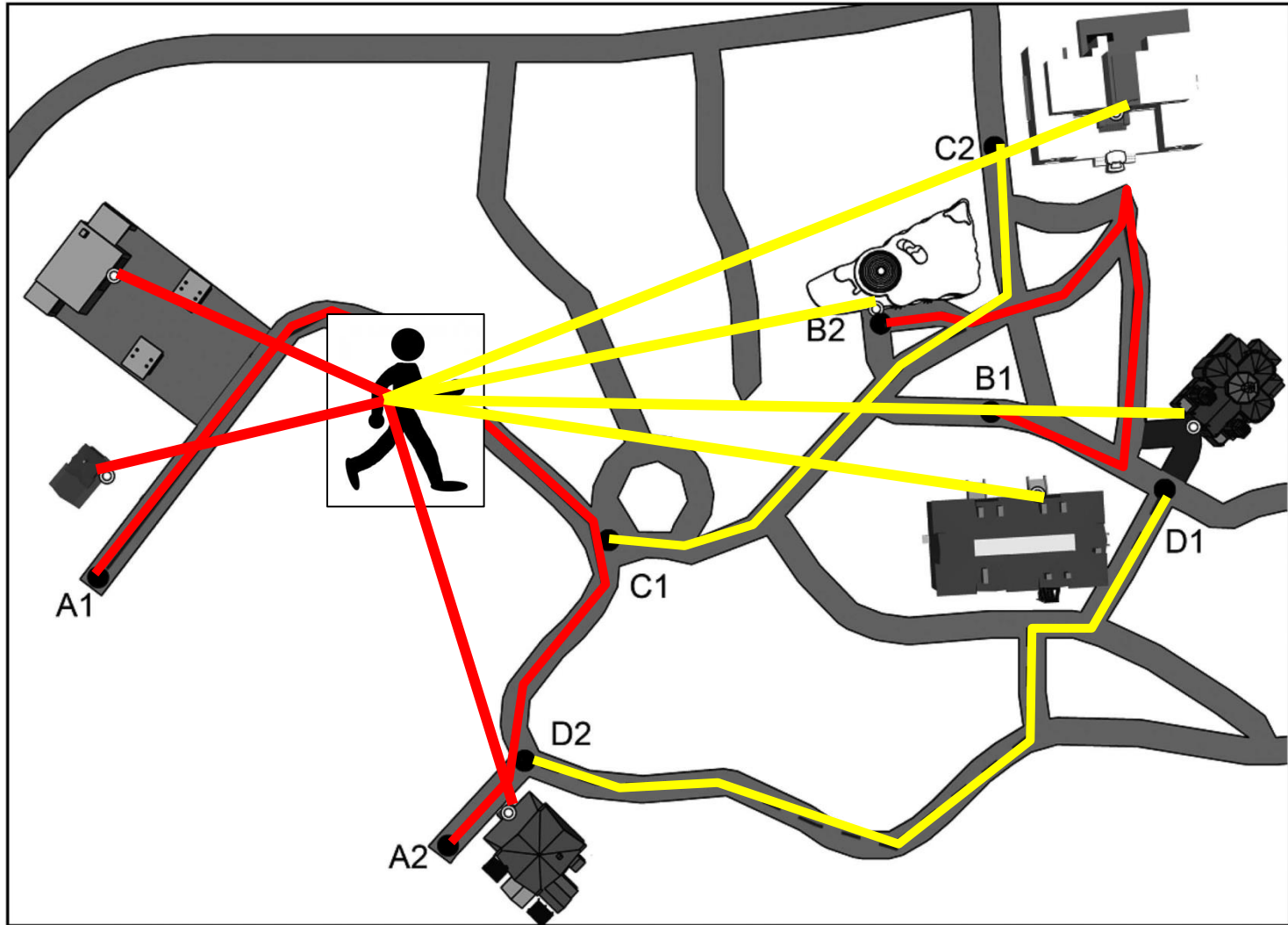
VIDEO REMOVED.

Onsite Pointing

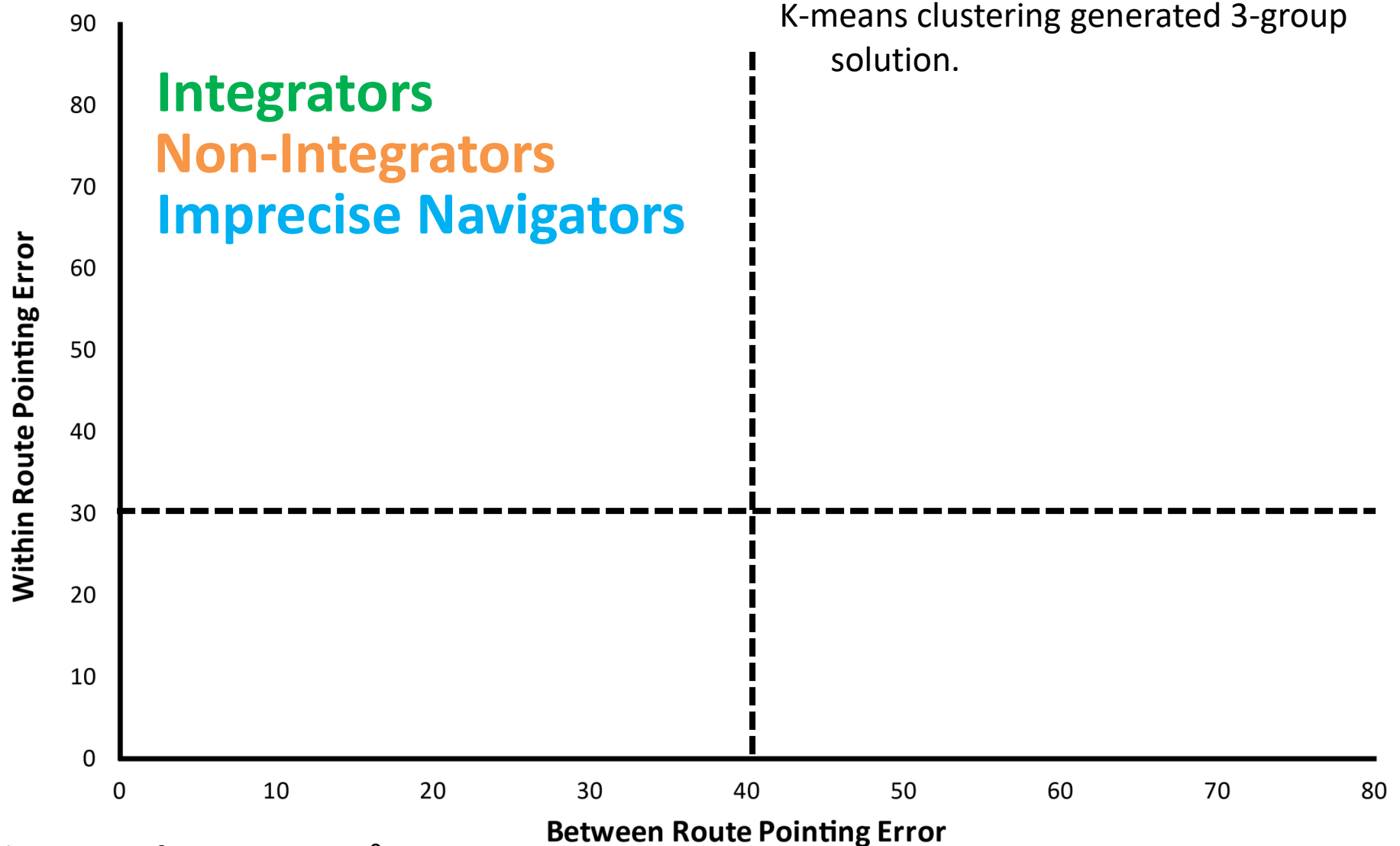


Weisberg et al. (2014) *JEP:LMC*; Weisberg & Newcombe (2016) *JEP:LMC*

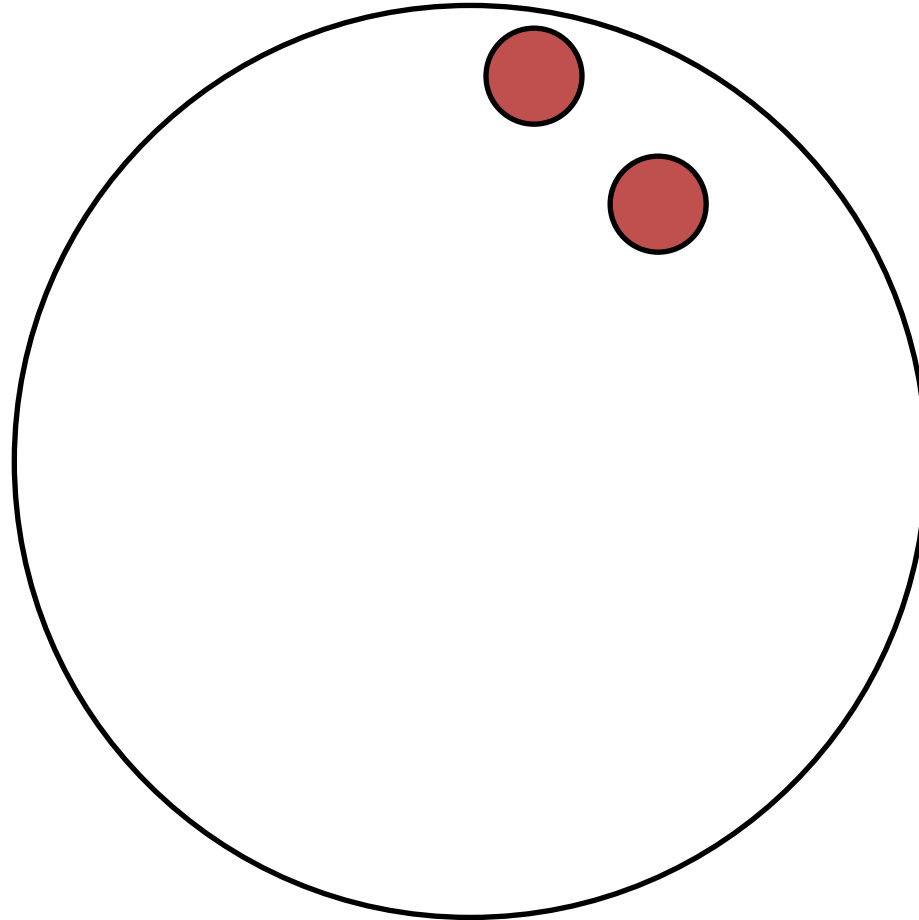
Onsite Pointing



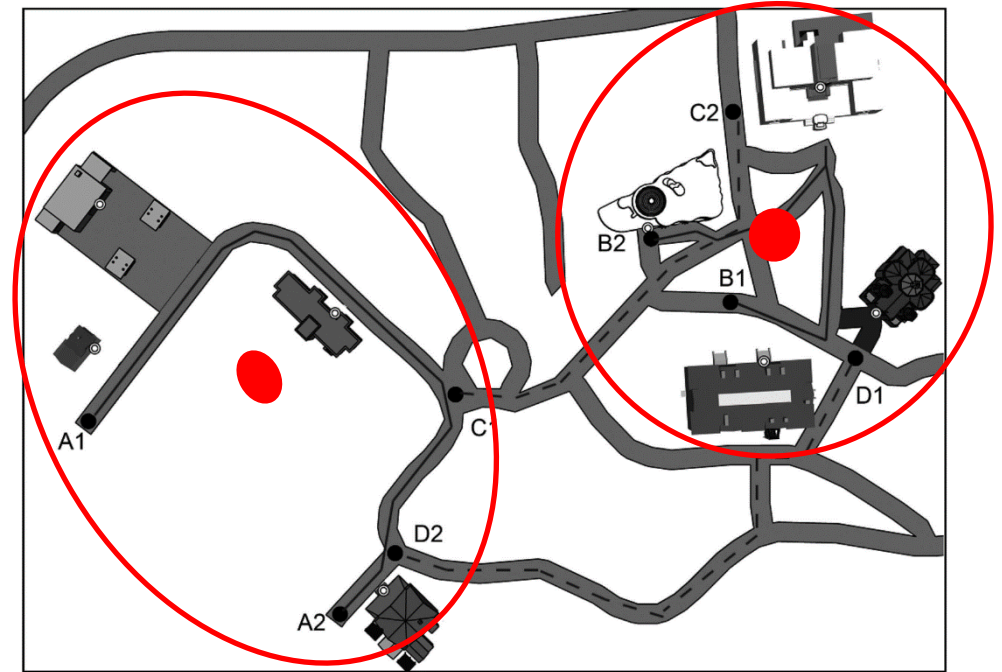
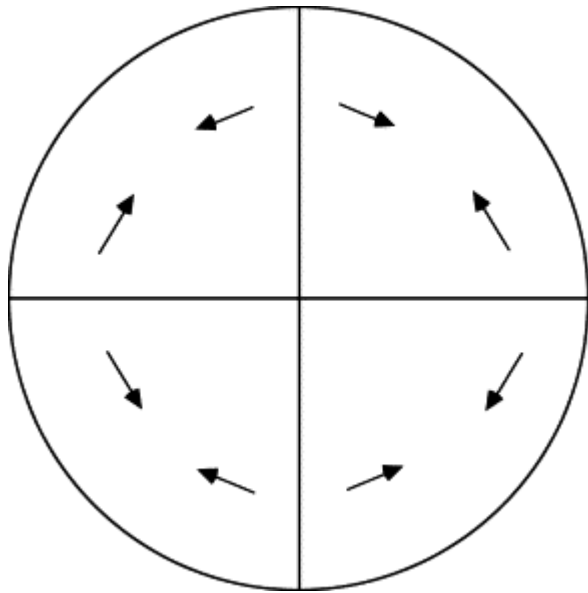
Two dimensions of individual differences



Category Adjustment Model



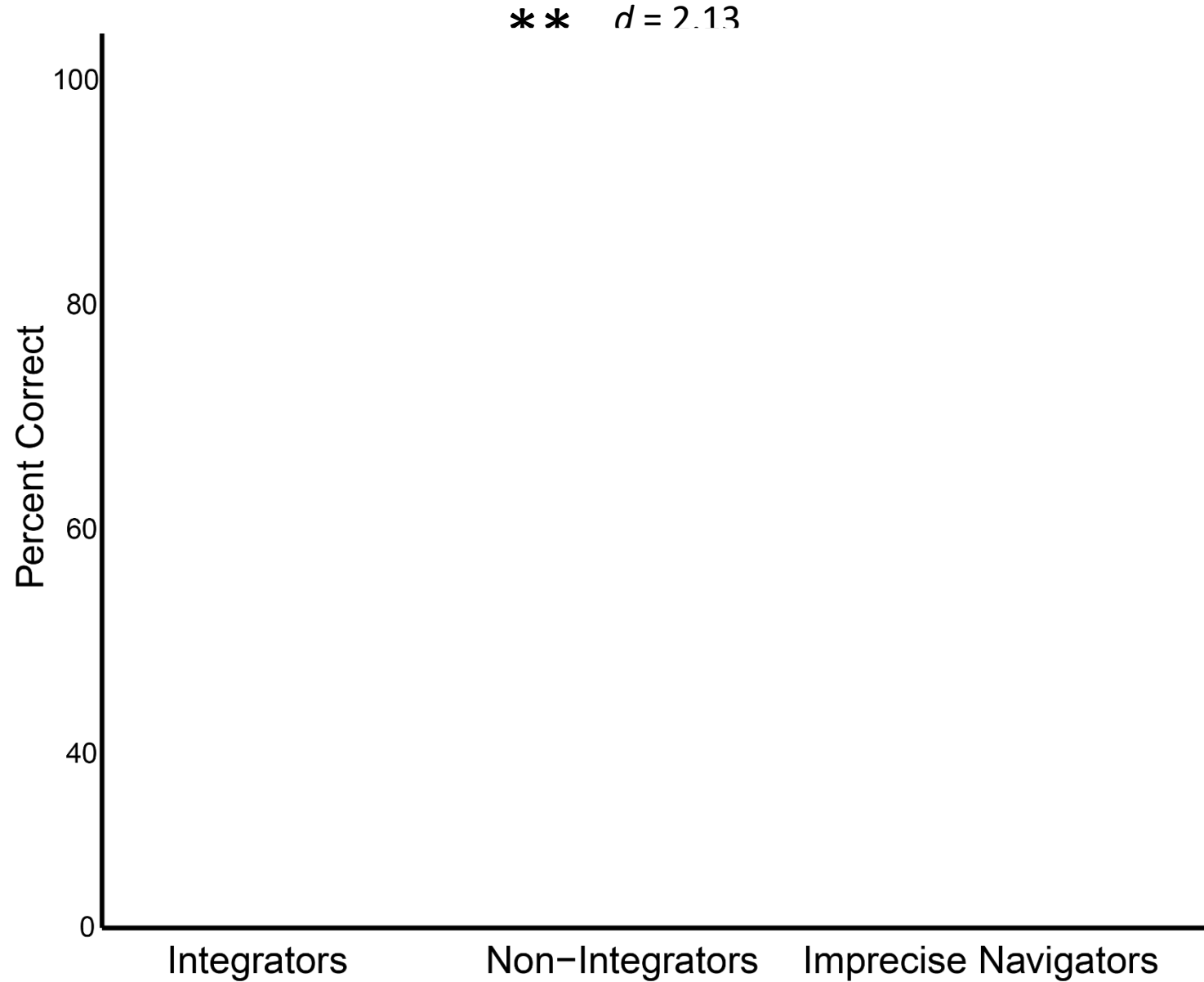
Do good navigators create categories?



Route Membership Task



Route Membership Task



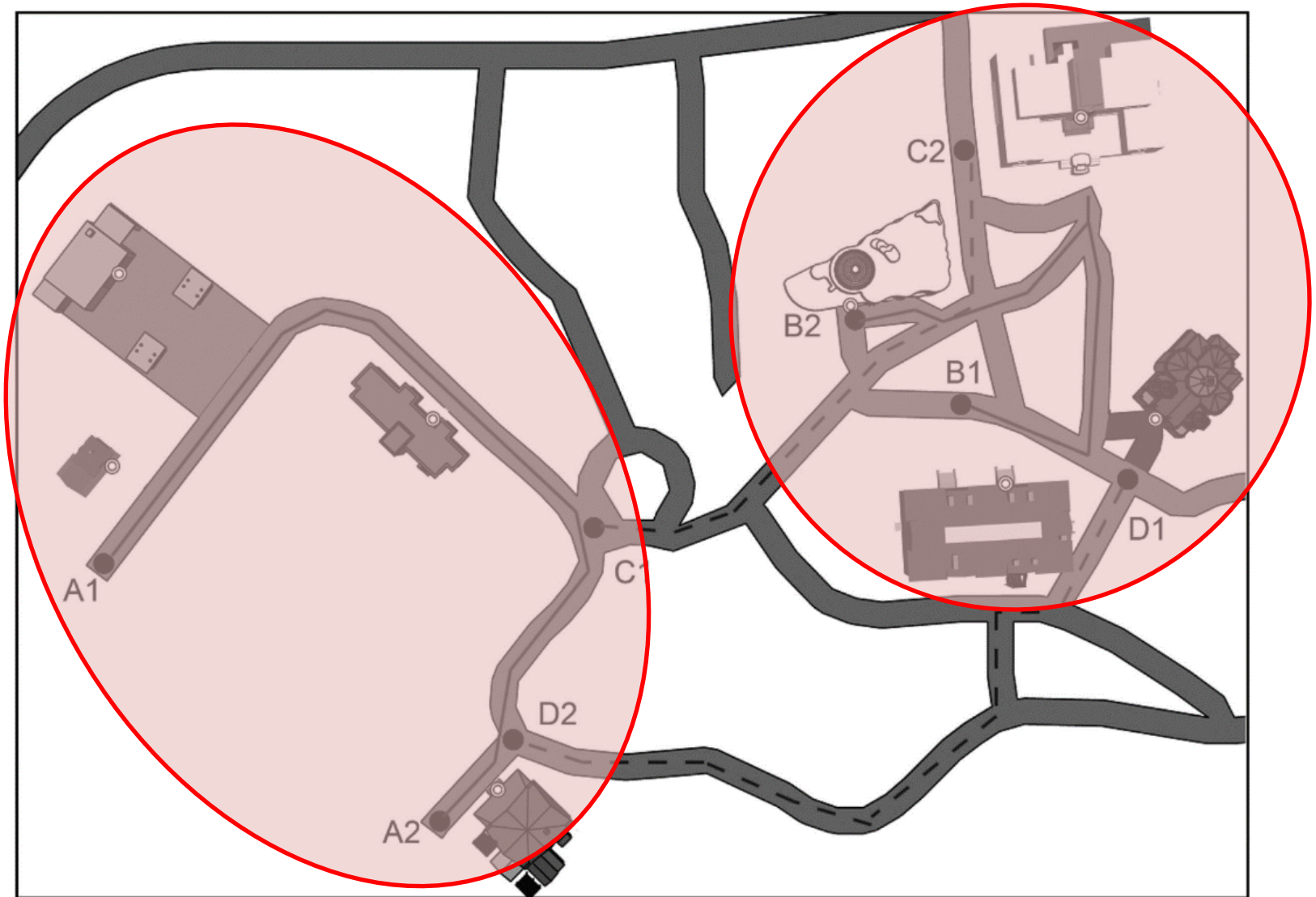
** $d = 2.13$

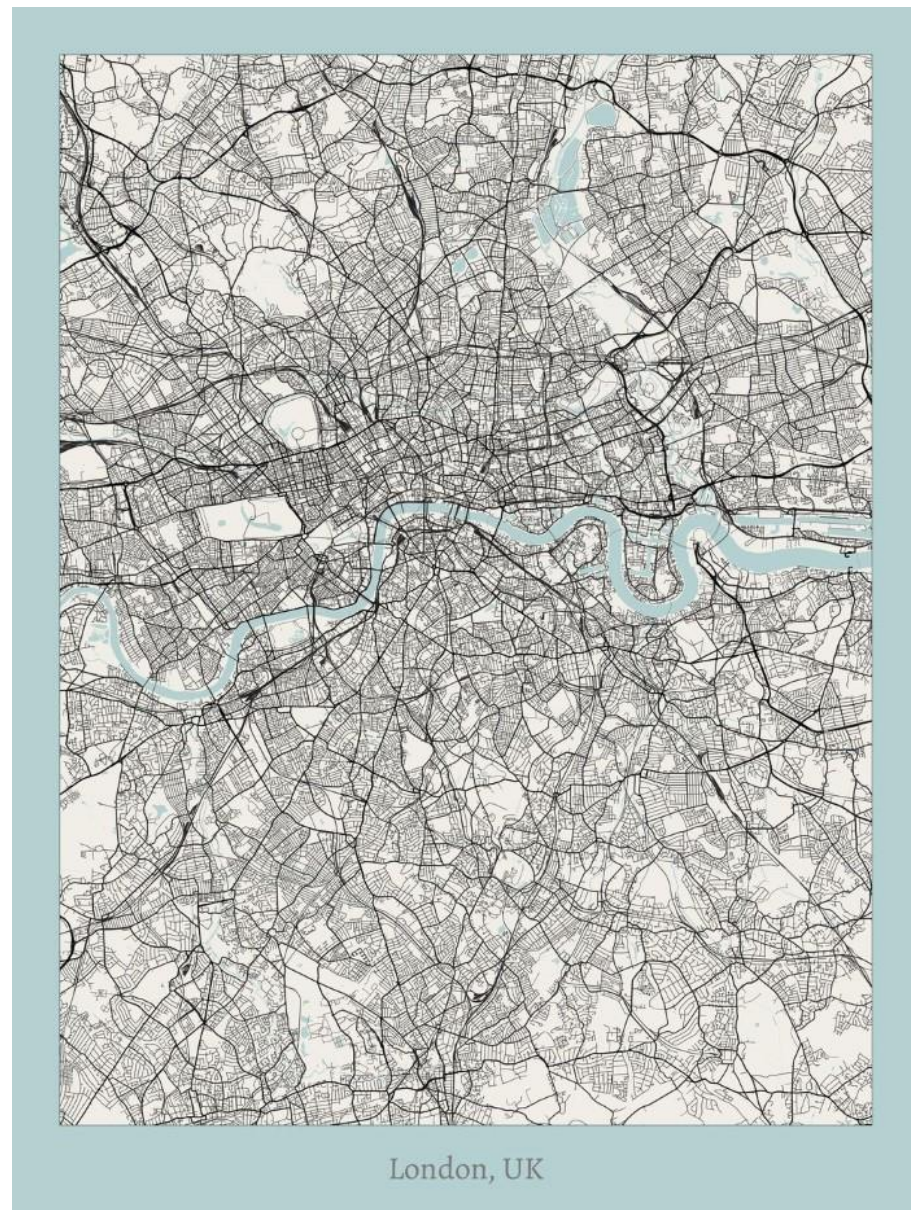
N = 76

* $p < .05$, ** $p < .01$

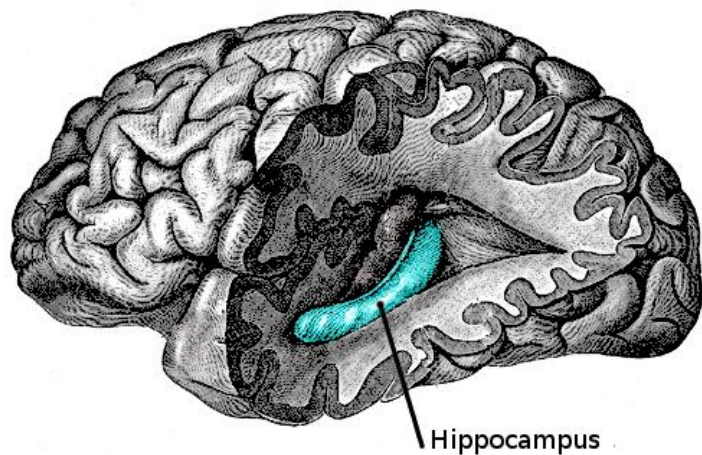
Weisberg & Newcombe (2016) *JEP:LMC*

Good navigators create categories





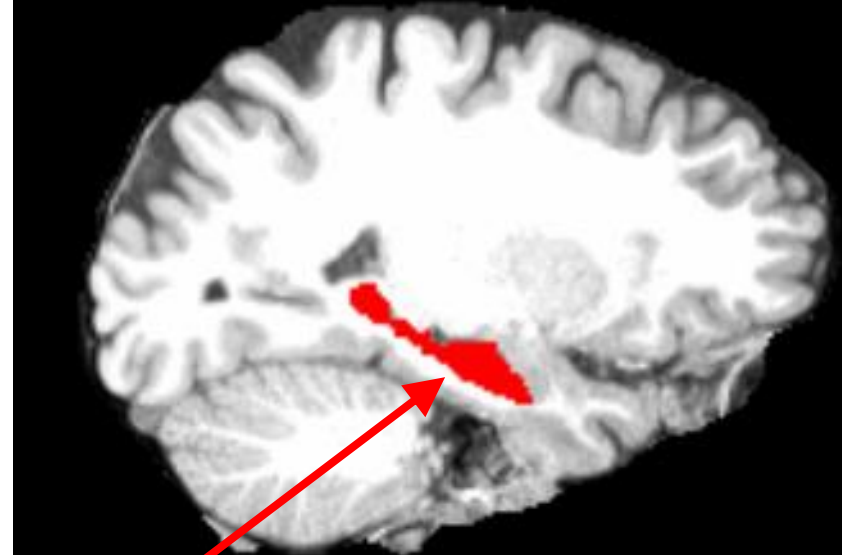
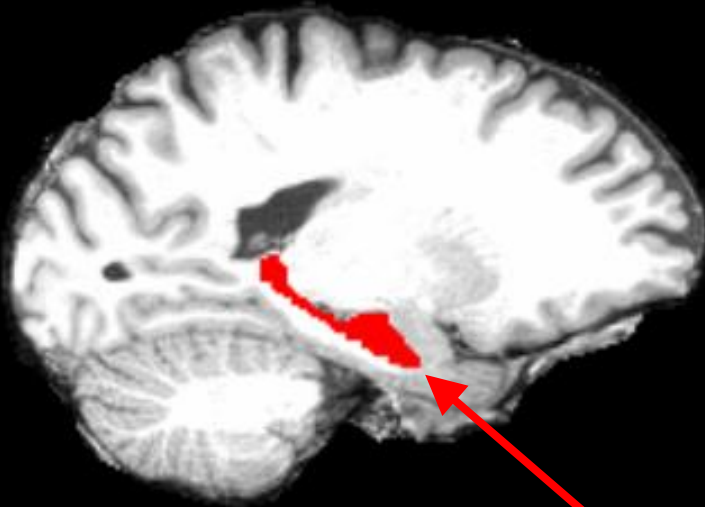
London, UK



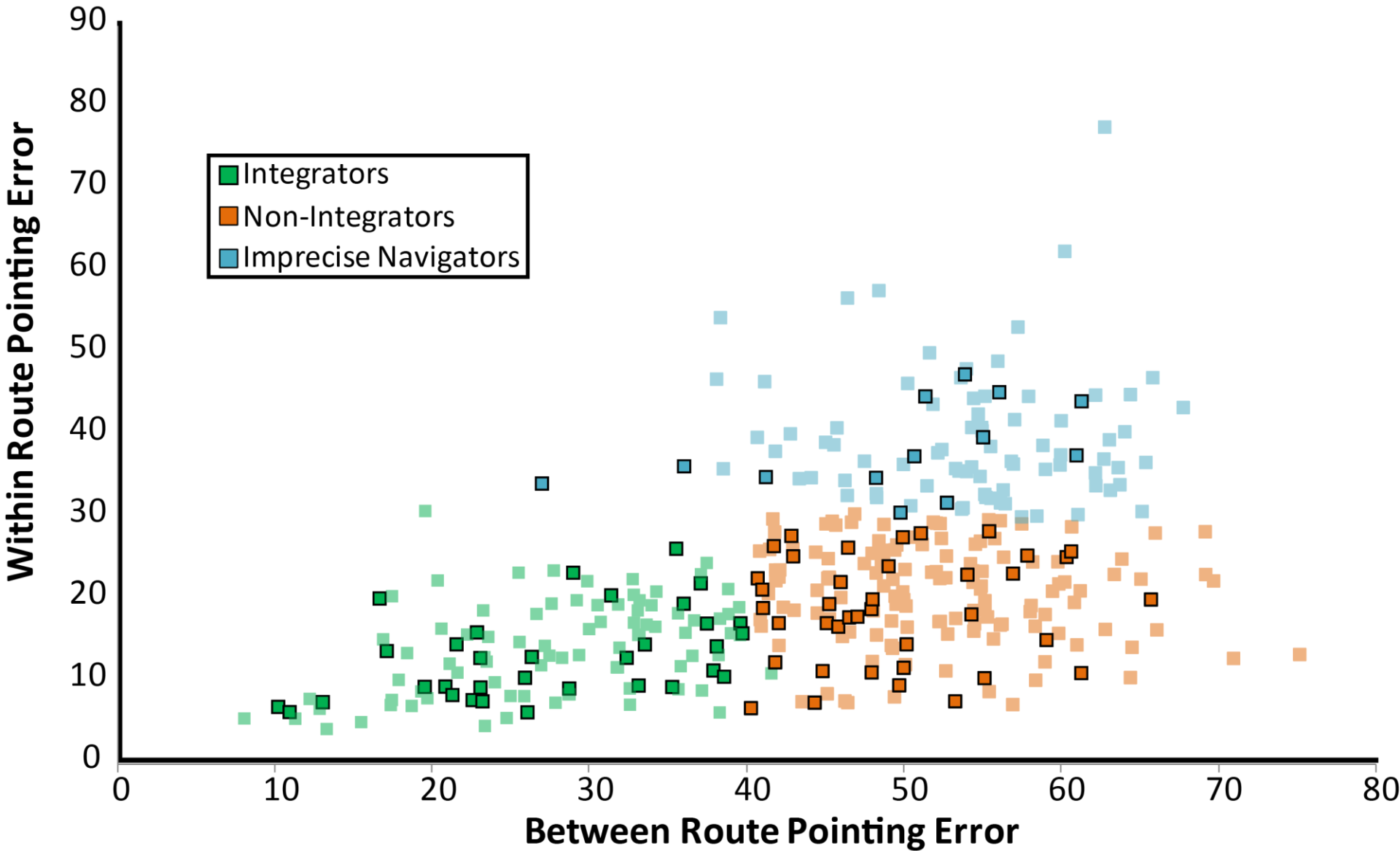
Hippocampus

Maguire et al. 2003; 2006

Everyday Taxi Drivers?



Hippocampus



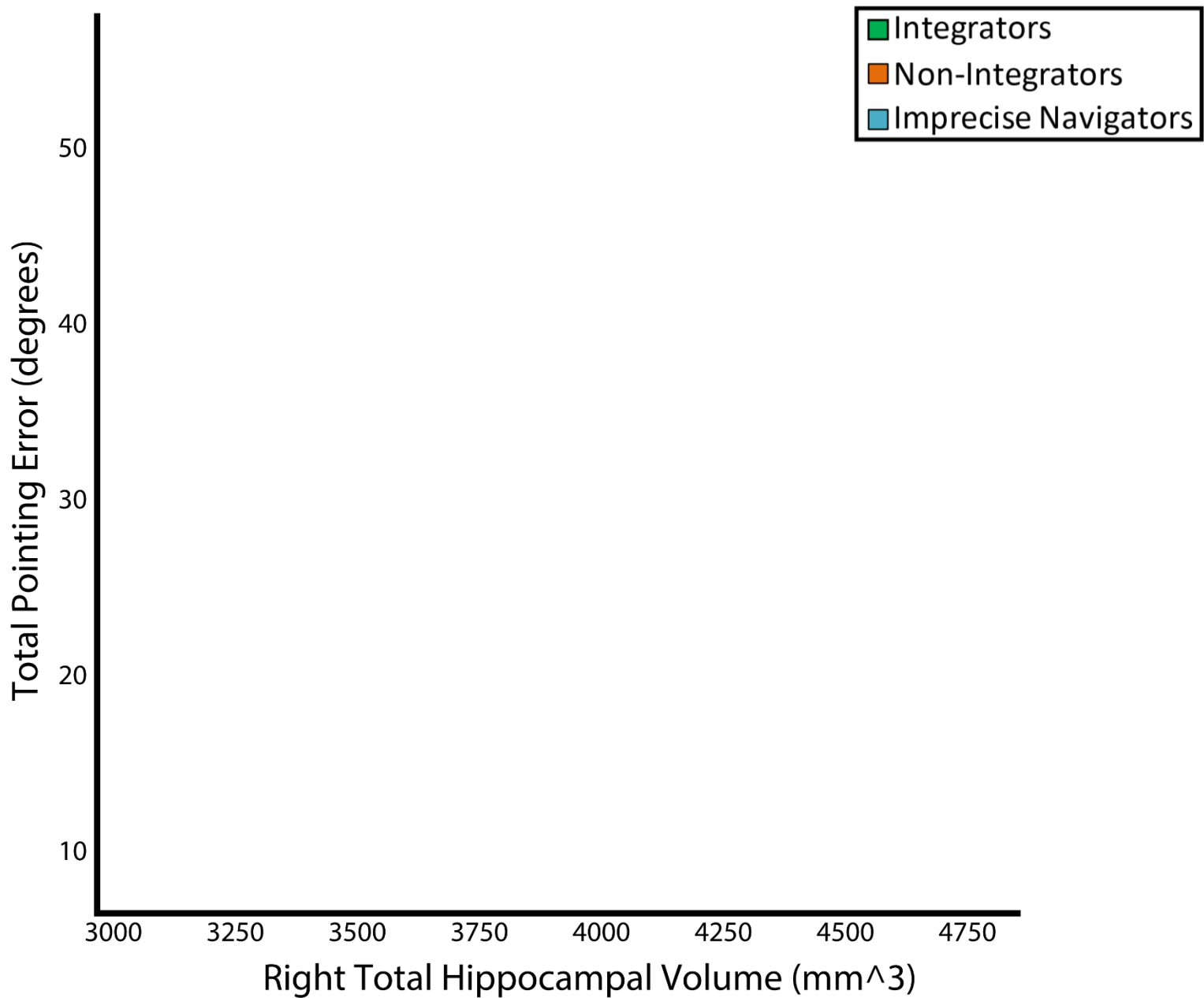
N = 90

Preregistered, open data, open code

The screenshot shows the OSFHOME project page for 'Silcton Hippocampal Volume'. The page is organized into several sections:

- Header:** OSFHOME logo and navigation links: My Quick Files, My Projects, Search, Support, Donate, and a user profile for Steven Weisberg.
- Project Title:** Silcton Hippocampal Volume with a 'Make Private' button, 'Public' status, and a '0' count.
- Contributors:** Steven Weisberg, Anjan Chatterjee, Nora Newcombe.
- Date created:** 2017-02-27 09:59 AM | Last Updated: 2019-01-17 03:26 PM.
- Identifier:** DOI 10.17605/OSF.IO/EA99D.
- Category:** Project.
- Description:** Add a brief description to your project.
- License:** Add a license.
- Wiki:** This is the official registration and data and code repository for the Silcton Hippocampal volume project (in submission, and on bioRxiv: <https://www.biorxiv.org/content/early/2018/09/29/431155>). There are two ways to view the data and code from this project.
 1. Check out the [Github repo](#), which hosts the public processed data, a codebook, and a viewable jupyter notebook with all analyses that appear...[Read More](#)
- Files:** Click on a storage provider or drag and drop to upload. A table lists files:

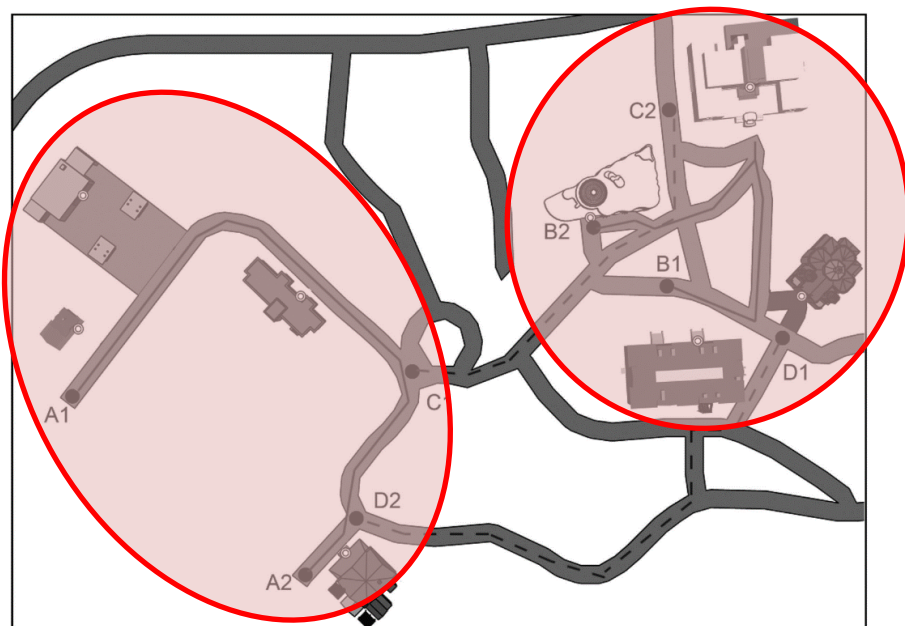
Name	Modified
Silcton Hippocampal Volume	
GitHub: smweis/Silcton_MRI (master)	
OSF Storage (United States)	
Archived Materials For Cortex Paper	
DataAnalysisWith70Participants.xlsx	2017-04-06 03:20 PM
- Citation:** A dropdown menu for citation options.
- Components:** Add Component and Link Projects buttons. Add components to organize your project.
- Tags:** hippocampal volume x hippocampus x MRI x spatial cognition x spatial navigation x Add a tag
- Recent Activity:**
 - Steven Weisberg approved embargoed registration of Silcton Hippocampal Volume (2019-01-17 03:26 PM)
 - Embargo for Silcton Hippocampal Volume completed (2019-01-12 12:00 AM)



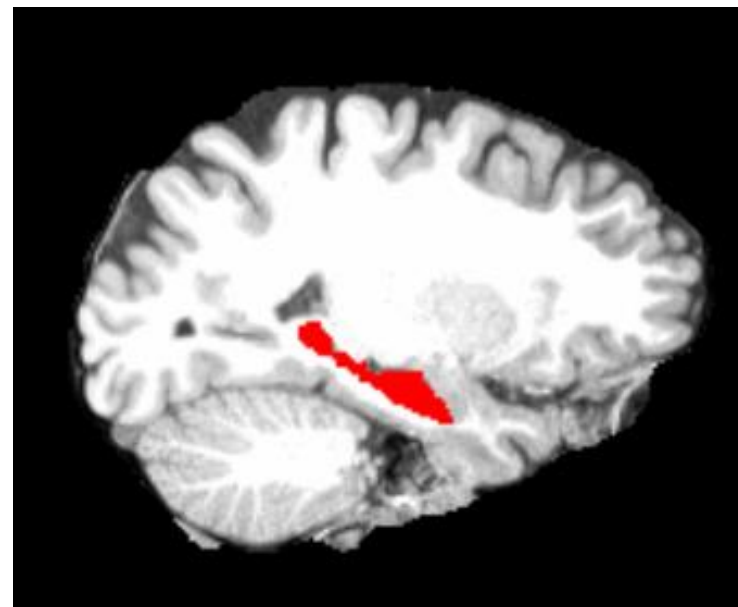
N = 90

Weisberg, Newcombe, & Chatterjee (2019) *Cortex*

How do people construct large-scale spatial representations?

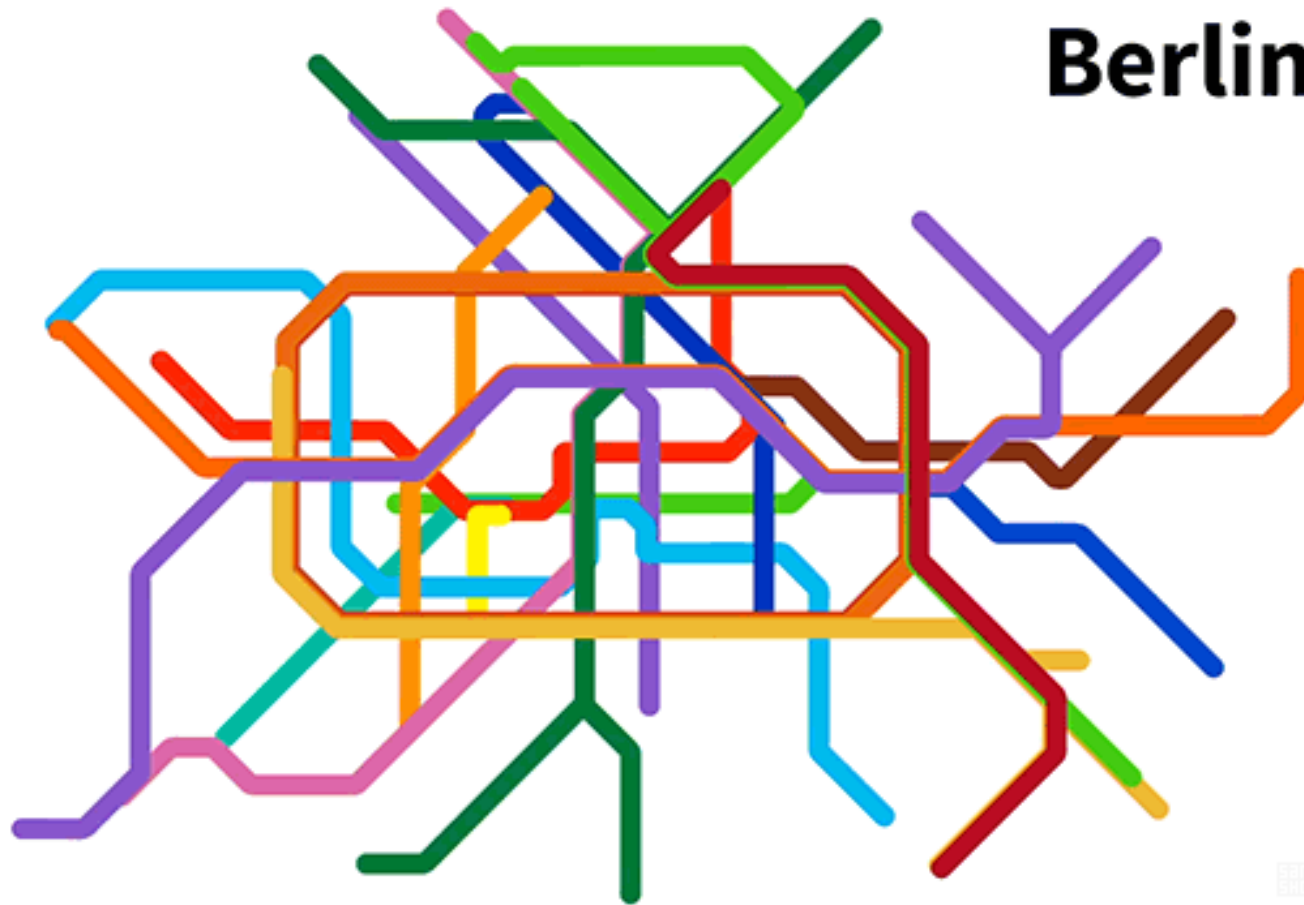


Categorization



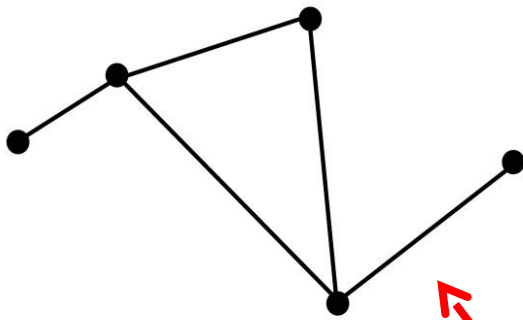
Non-hippocampal strategies

Future Direction: Cognitive Map or Cognitive Graph?

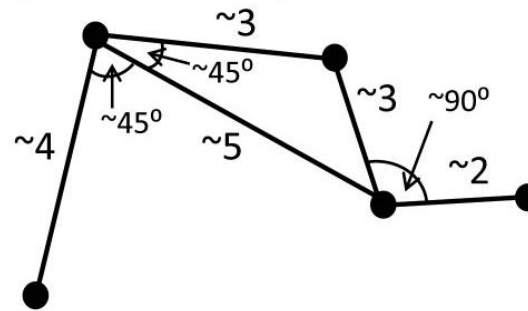


Future Direction: Individual Differences in Spatial Representations

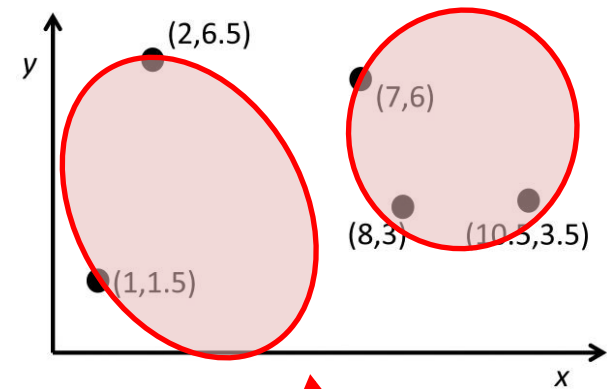
a) Graph



b) Labeled Graph



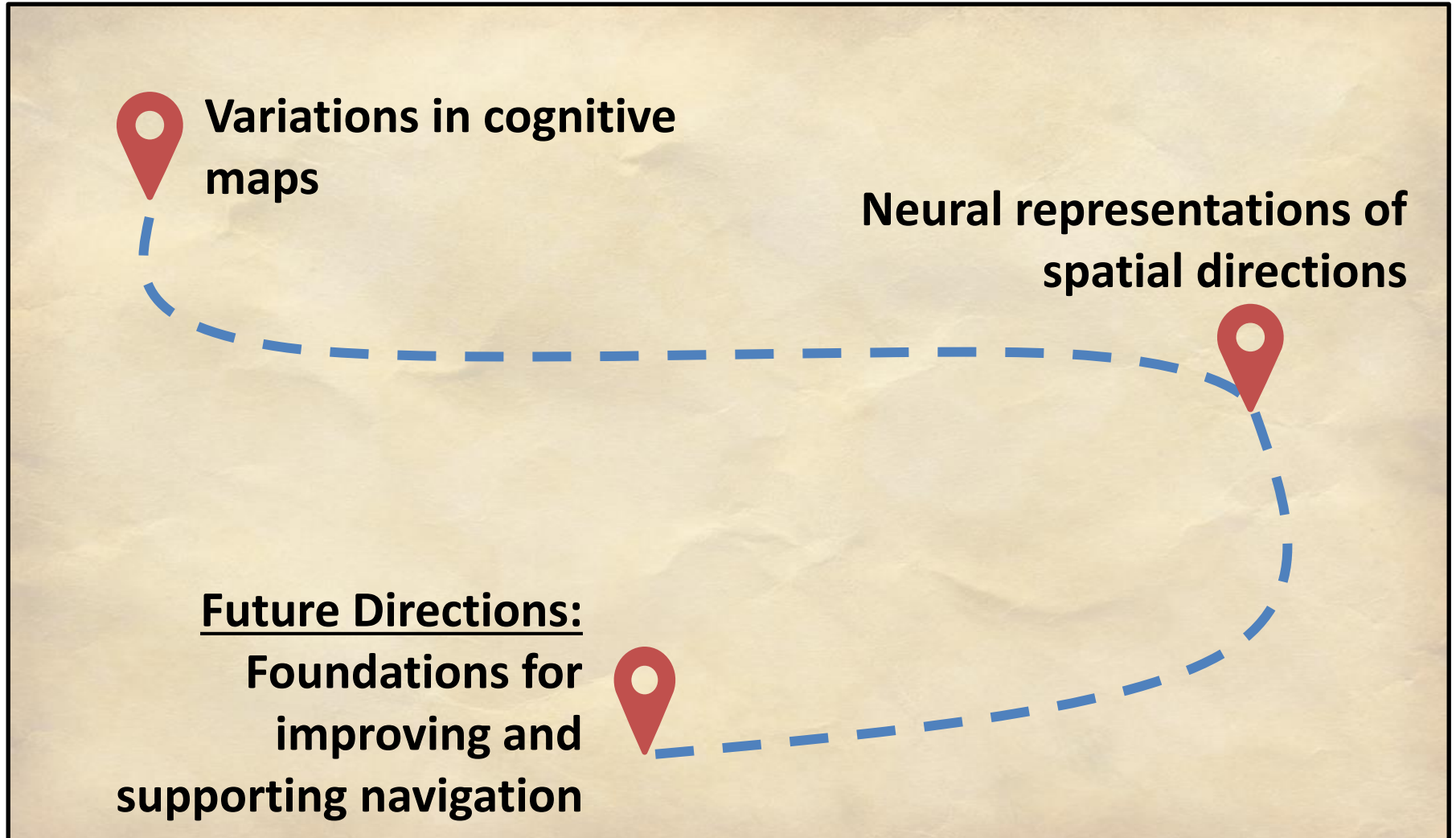
c) Survey

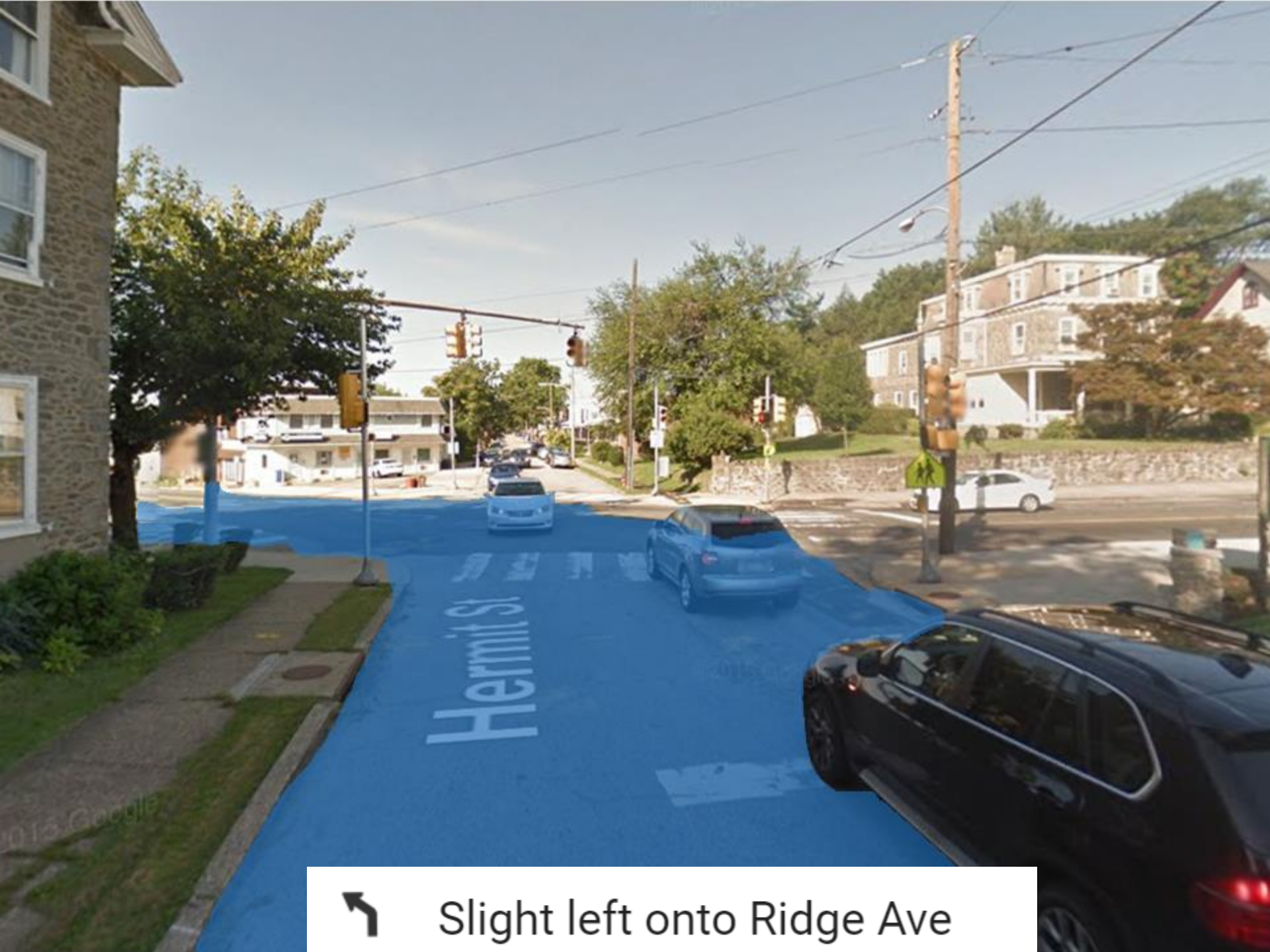


Imprecise
Navigators?

Integrators?

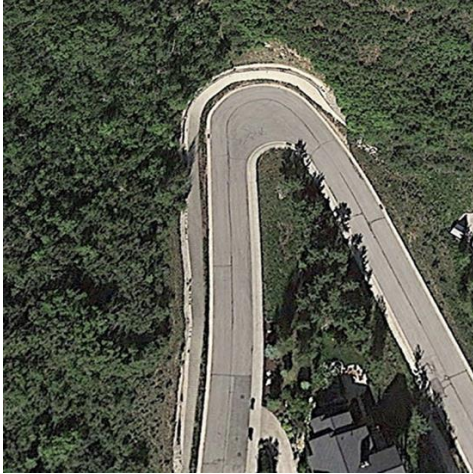
Our Road Map





Slight left onto Ridge Ave

Images



Schemas



Words

sharp
right

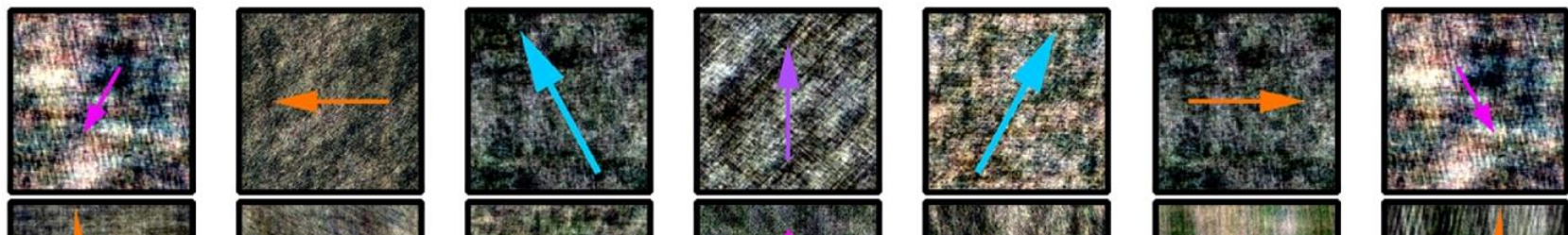
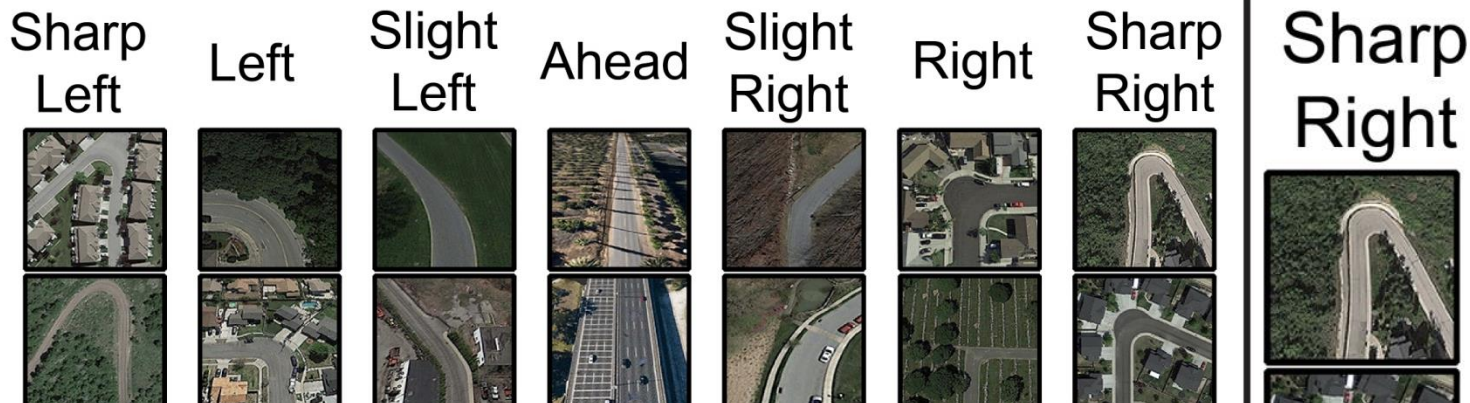


SLAM
DUNK

How does the brain encode spatial directions
across formats?

Images

Images



Words



fMRI Method

One-back task for **Catch Trials Only** (Accuracy = 89.9%)



SAME?

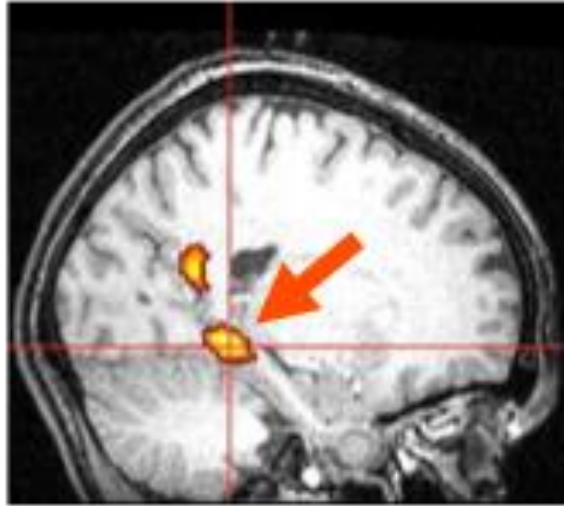
fMRI Method

One-back task for **Catch Trials Only** (Accuracy = 89.9%)

Continuous Carryover Trial Sequence (Aguirre, 2007)

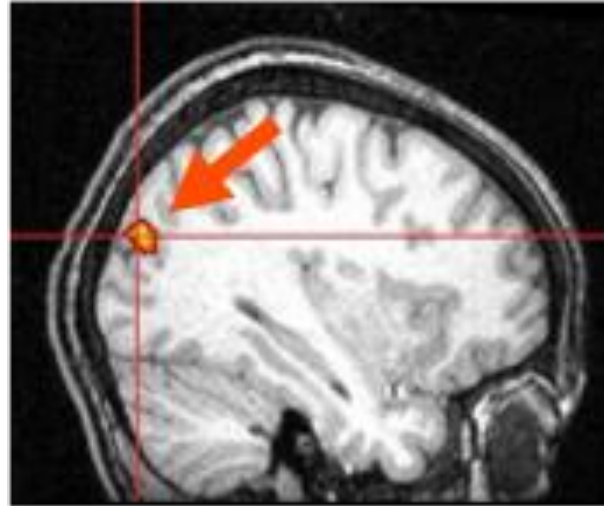
~**600 total trials** (including catch + null trials)

Regions of Interest: Visual Scene Regions



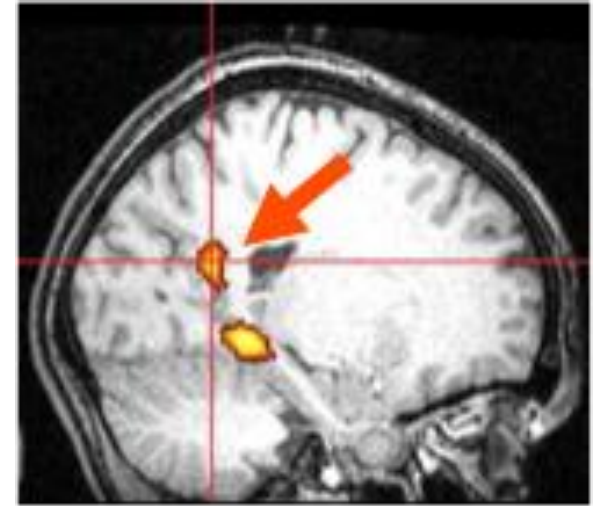
PPA

parahippocampal place
area



OPA

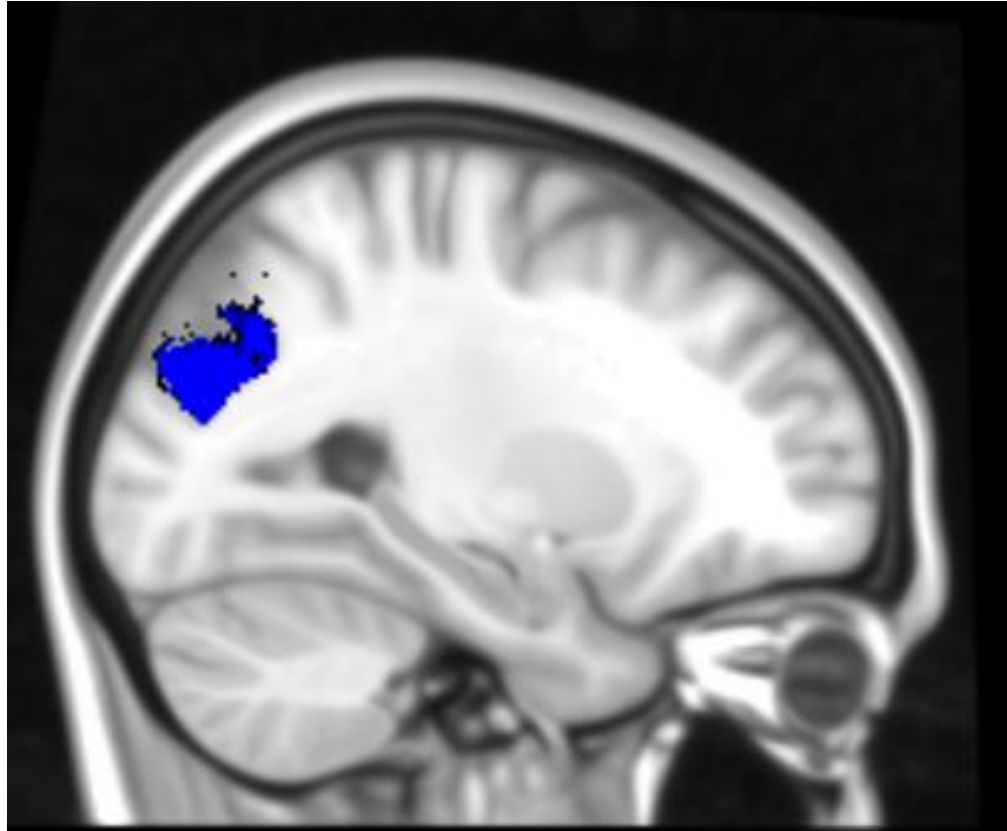
occipital place area



RSC

retrosplenial complex

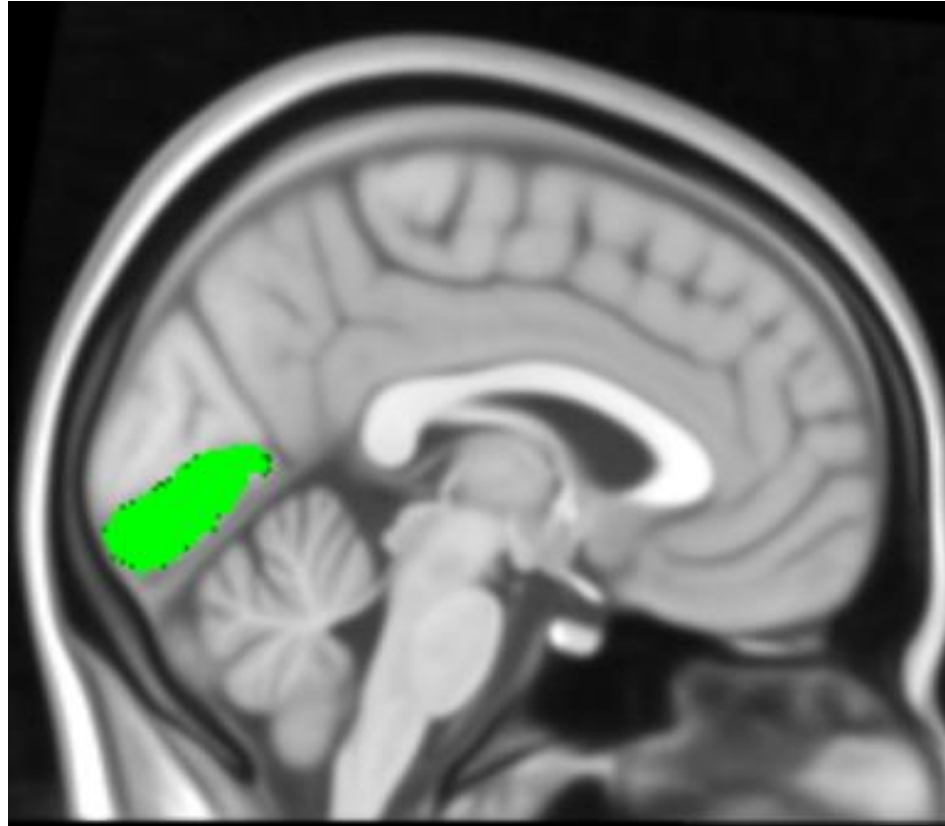
Regions of Interest: Spatial Directions



IPS

Intraparietal sulcus

Regions of Interest: Low Level Vision

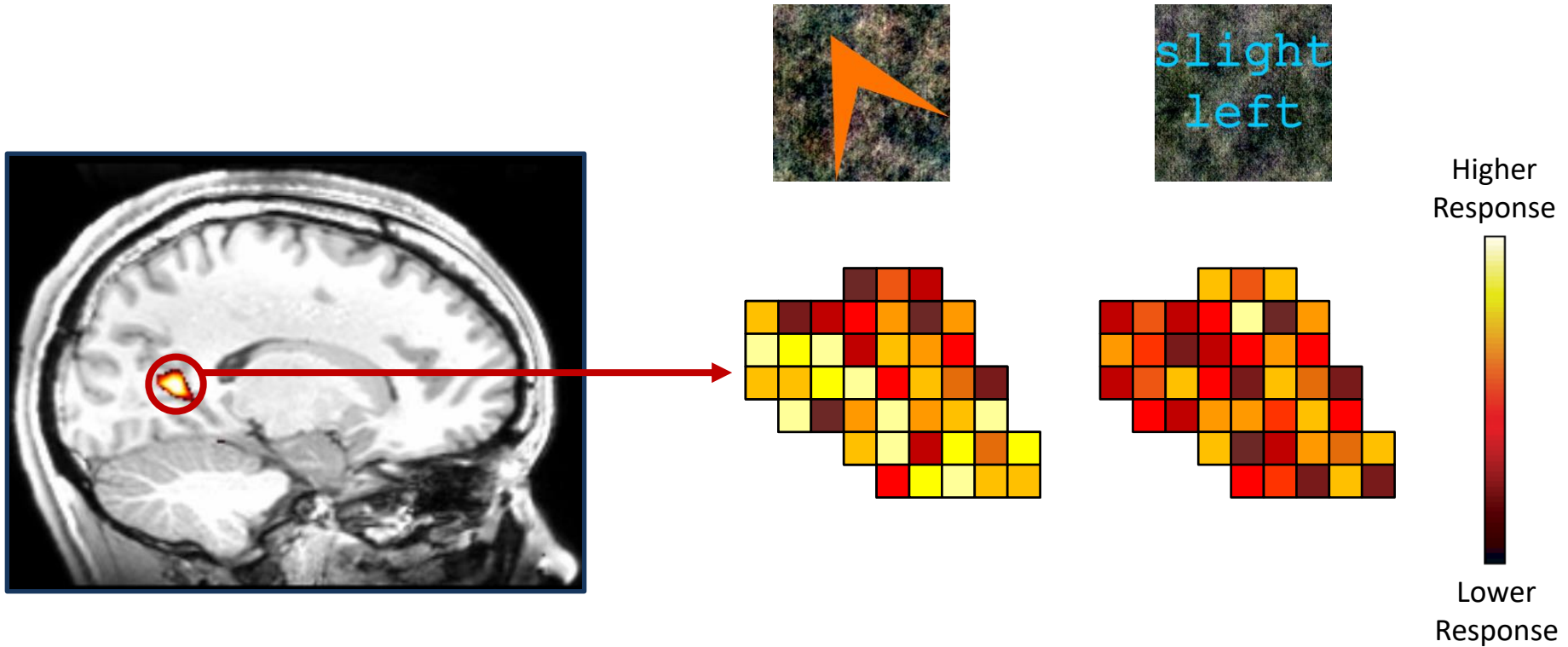


EVC

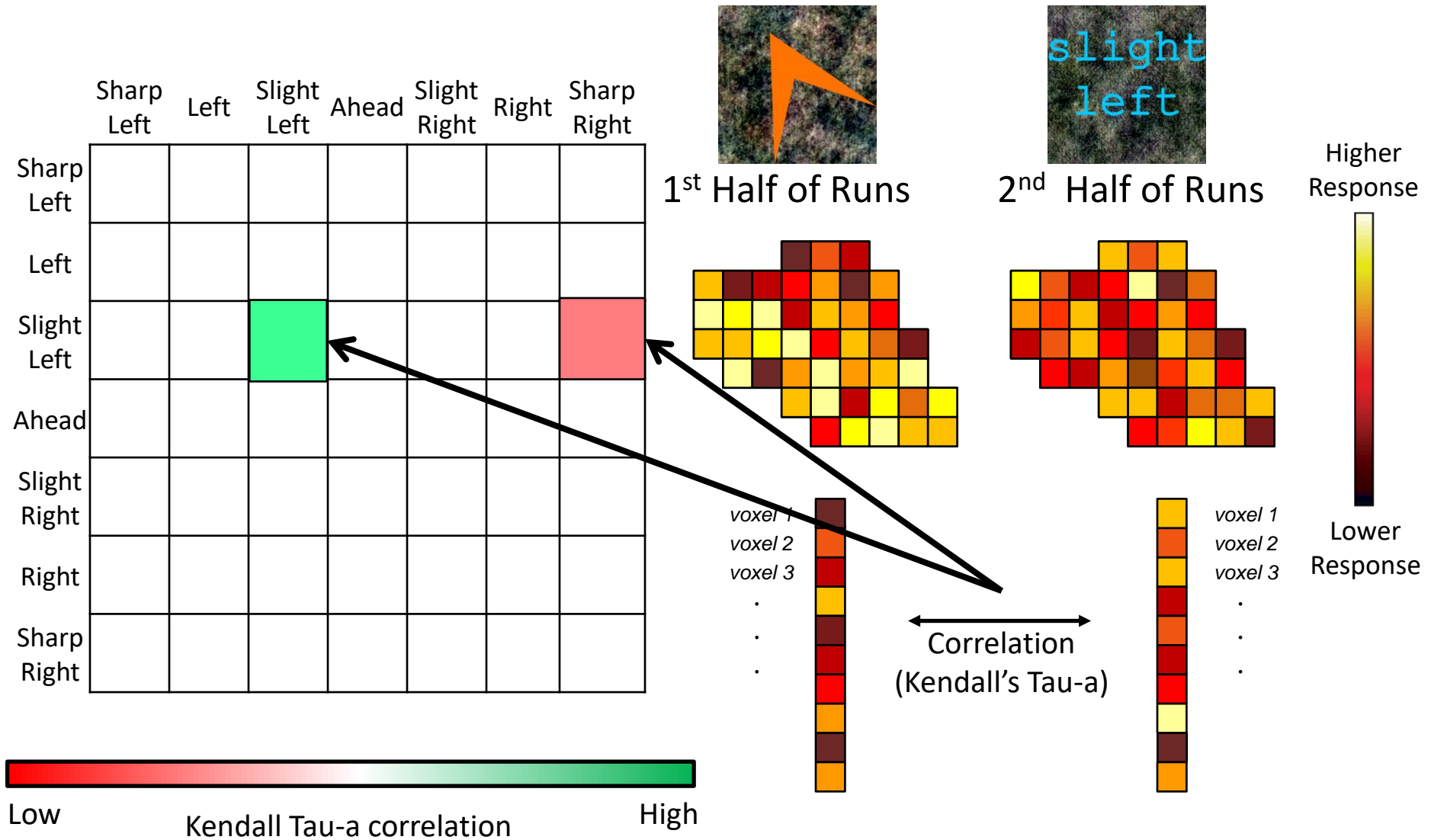
early visual
cortex

Multi-voxel Pattern Analysis (MVPA)

MVPA: Step 1 – Estimate Signal (per spatial direction and format)



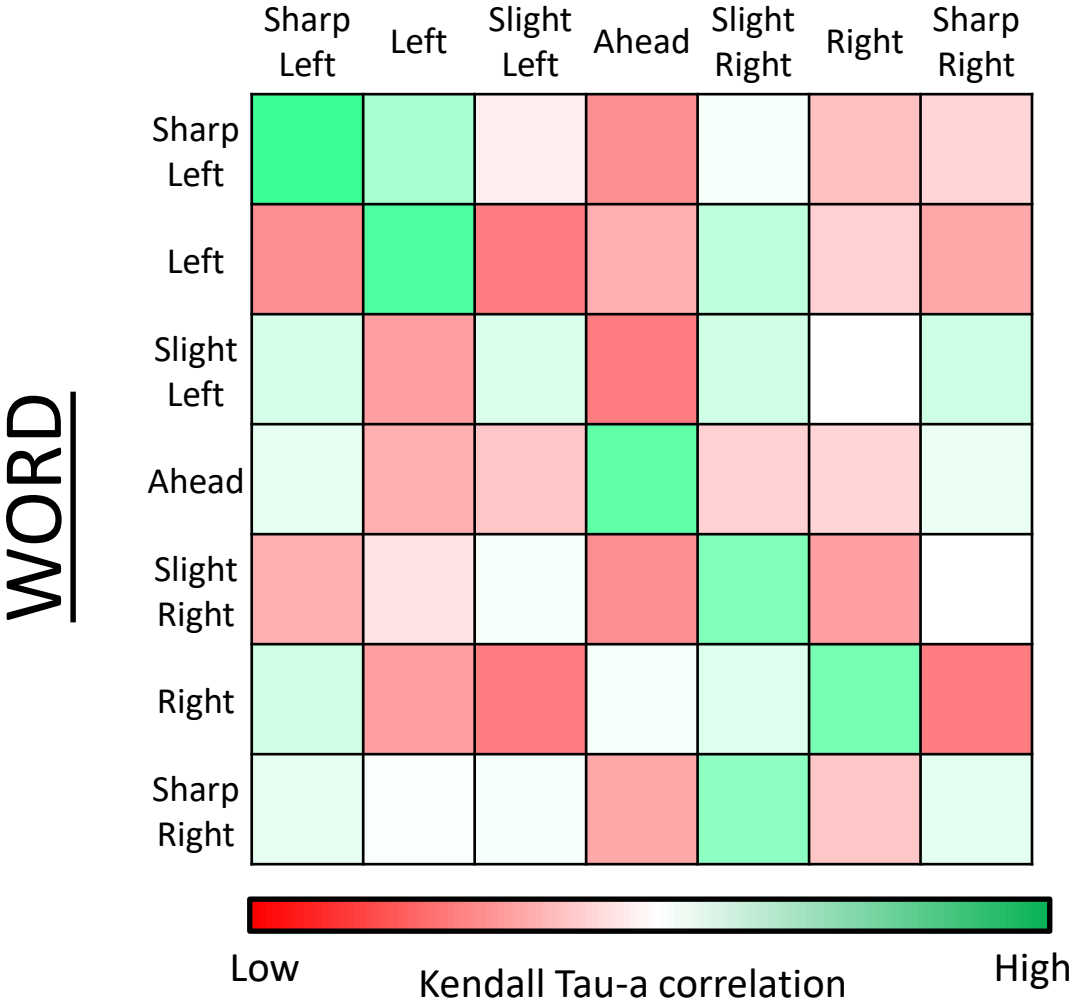
MVPA: Step 2 – Create Correlation Matrix



Haxby (2002); Kriegeskorte (2008)

MVPA: Step 2 – Create Correlation Matrix

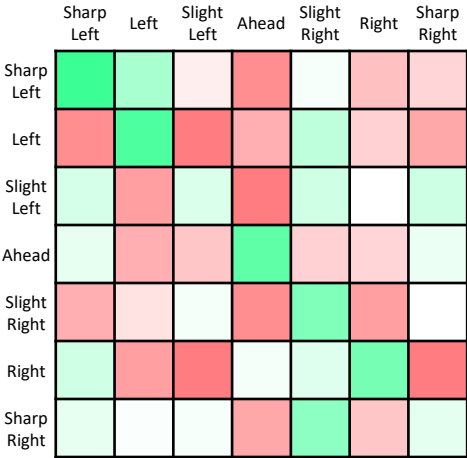
SCHEMA



MVPA: Step 2 – Create Correlation Matrix

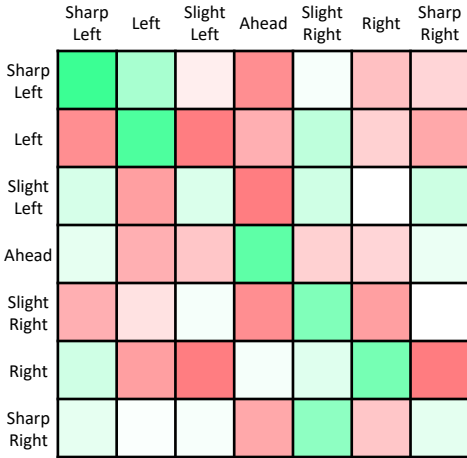
SCHEMA

WORD



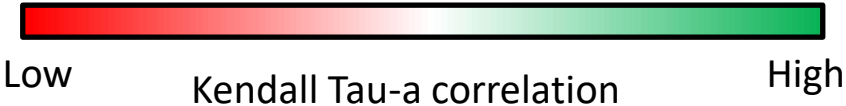
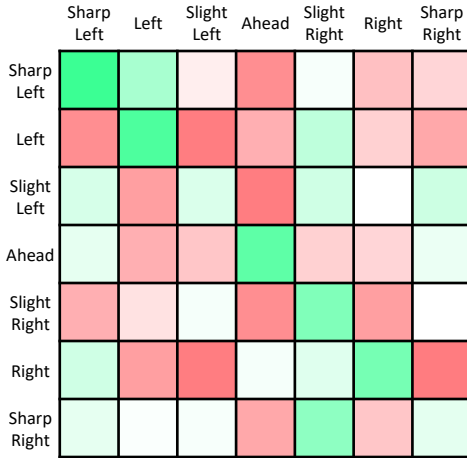
SCHEMA

IMAGE



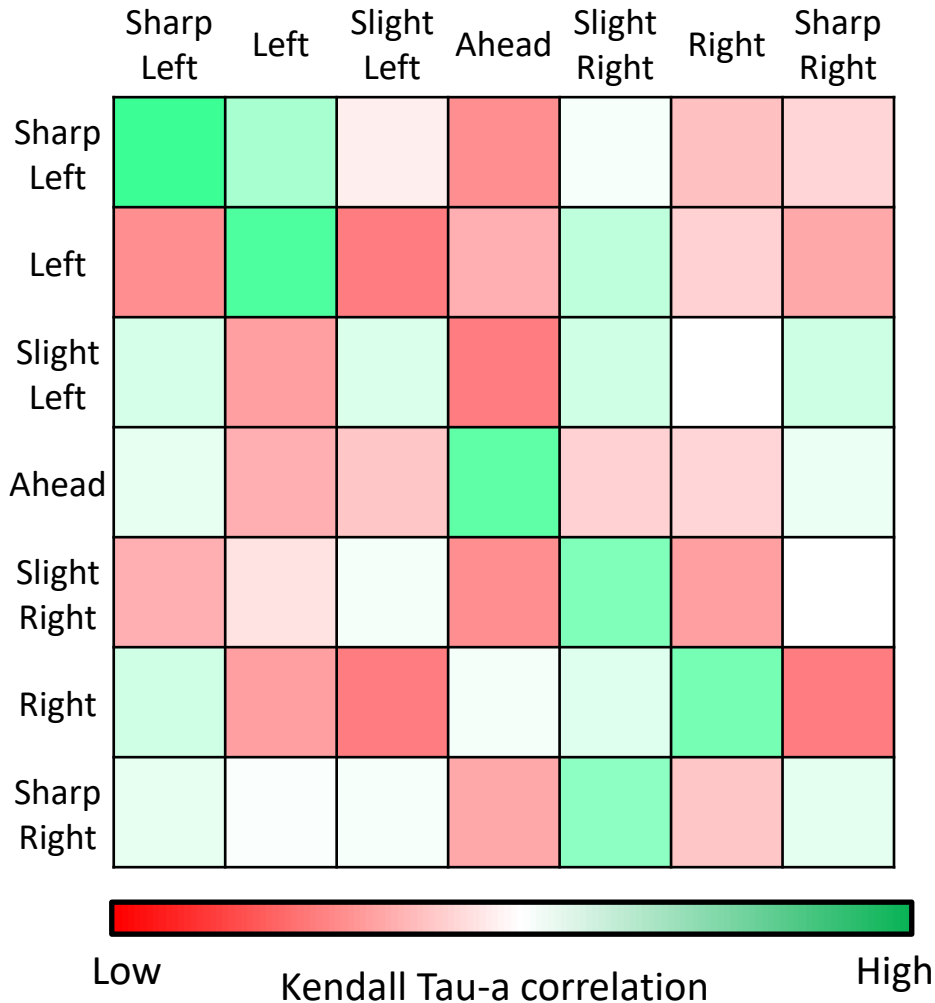
WORD

IMAGE

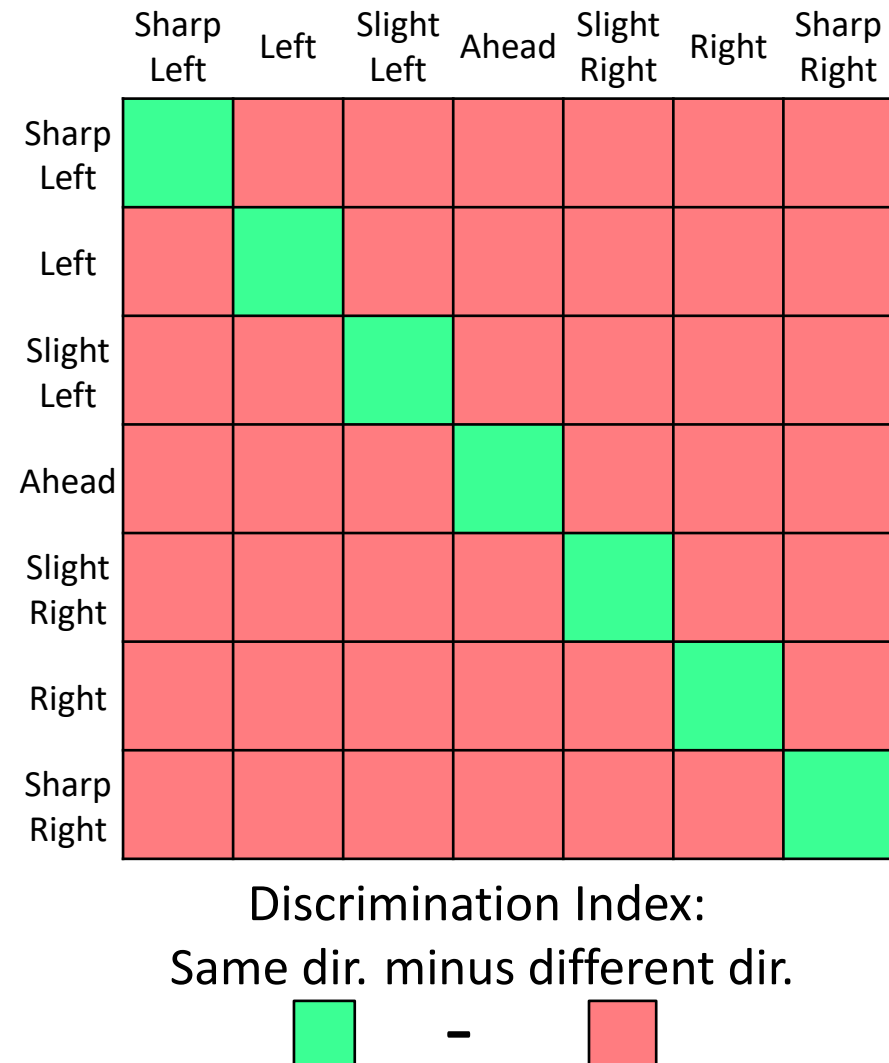


MVPA: Step 3 – Average correlations and test across subjects

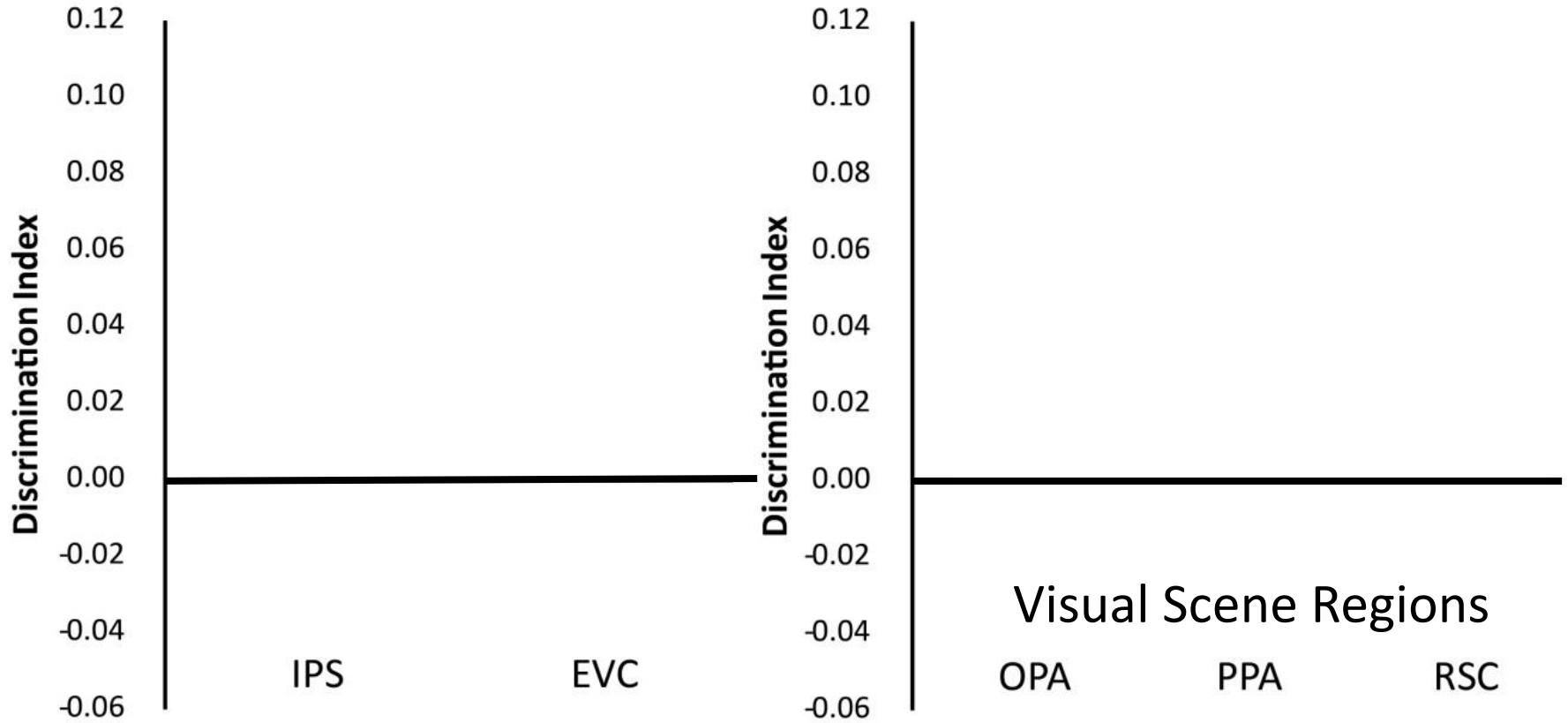
Neural Data



Ideal Data



Spatial Direction Decoding Across Format



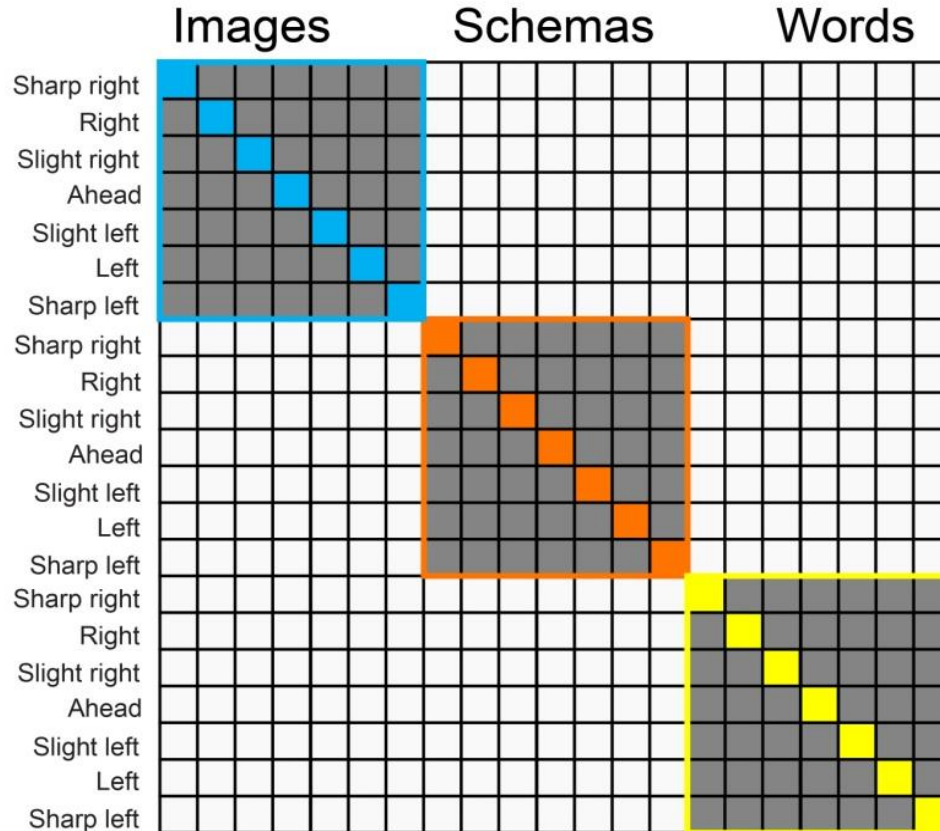
N = 24

* $p < .05$

Error bars = \pm SEM

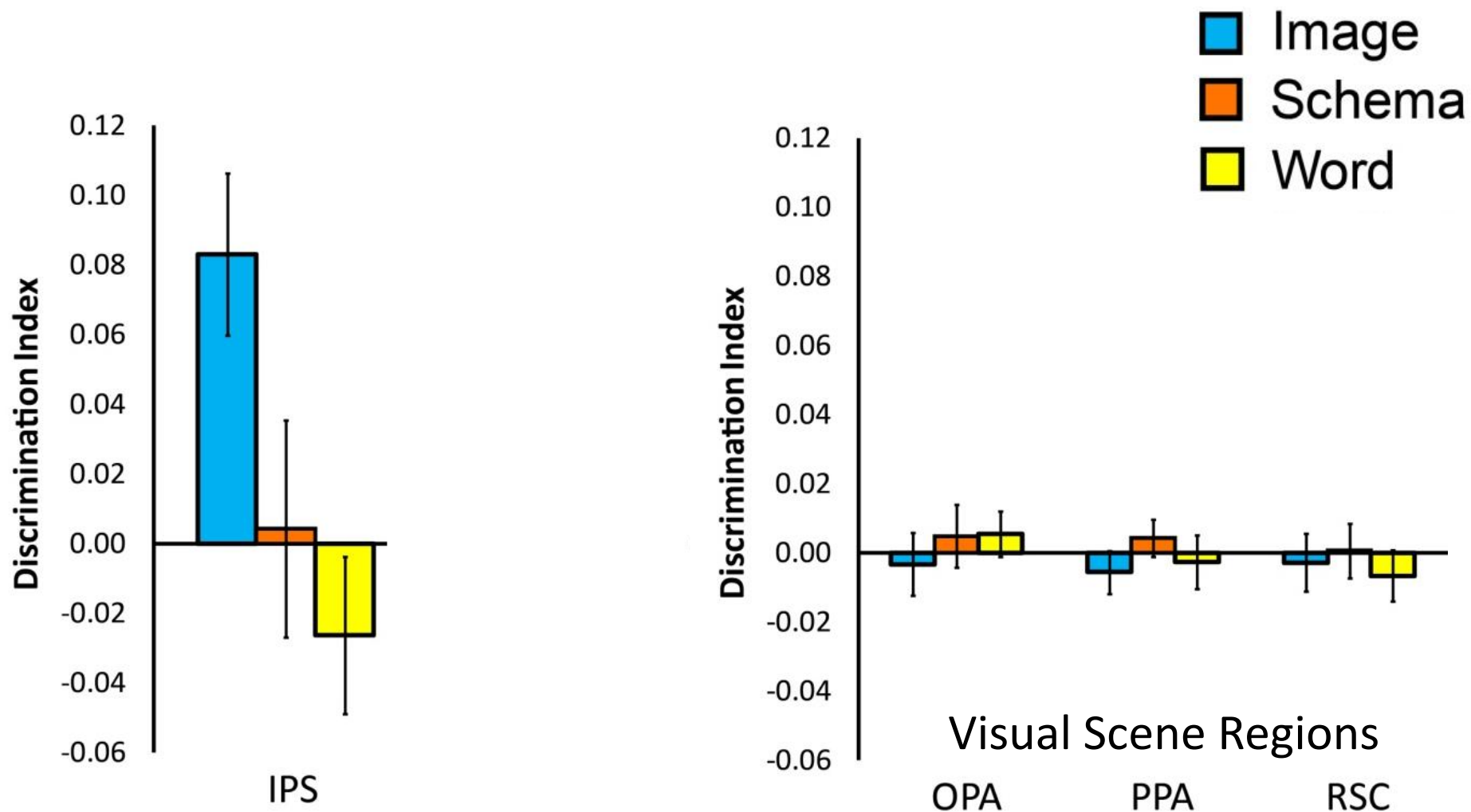
Weisberg, Marchette, & Chatterjee (2018), *J Neuro*

Spatial Direction Decoding Within Format



- - ■ = Image
- - ■ = Schema
- - ■ = Word
- = Omitted

Spatial Direction Decoding Within Format

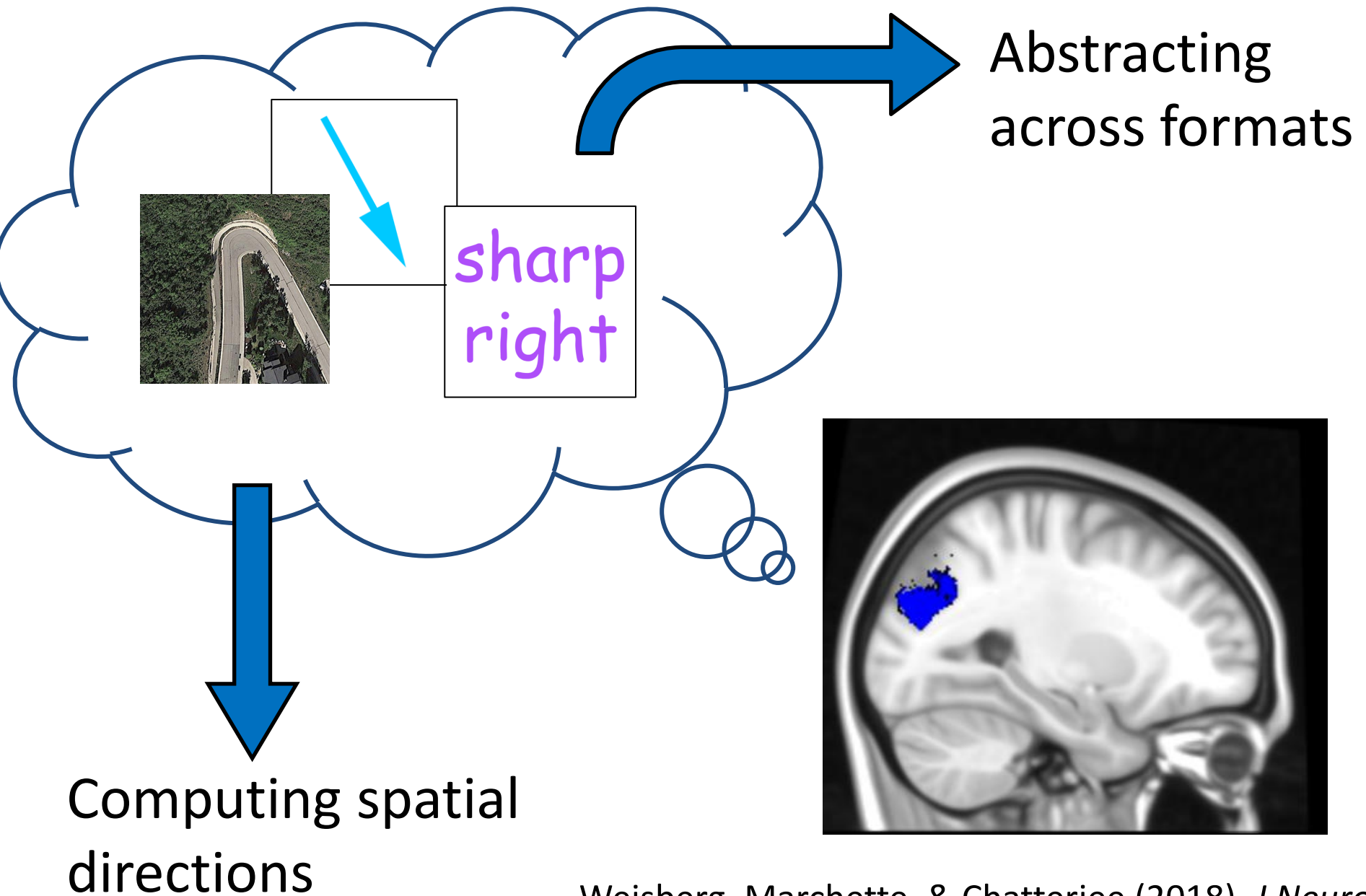


** $p < .01$

Error bars = \pm SEM

Weisberg, Marchette, & Chatterjee (2018), *J Neuro*

Theories of representation in IPS



Posterior
Cortical
Atrophy



Within-
format
trial
blocks



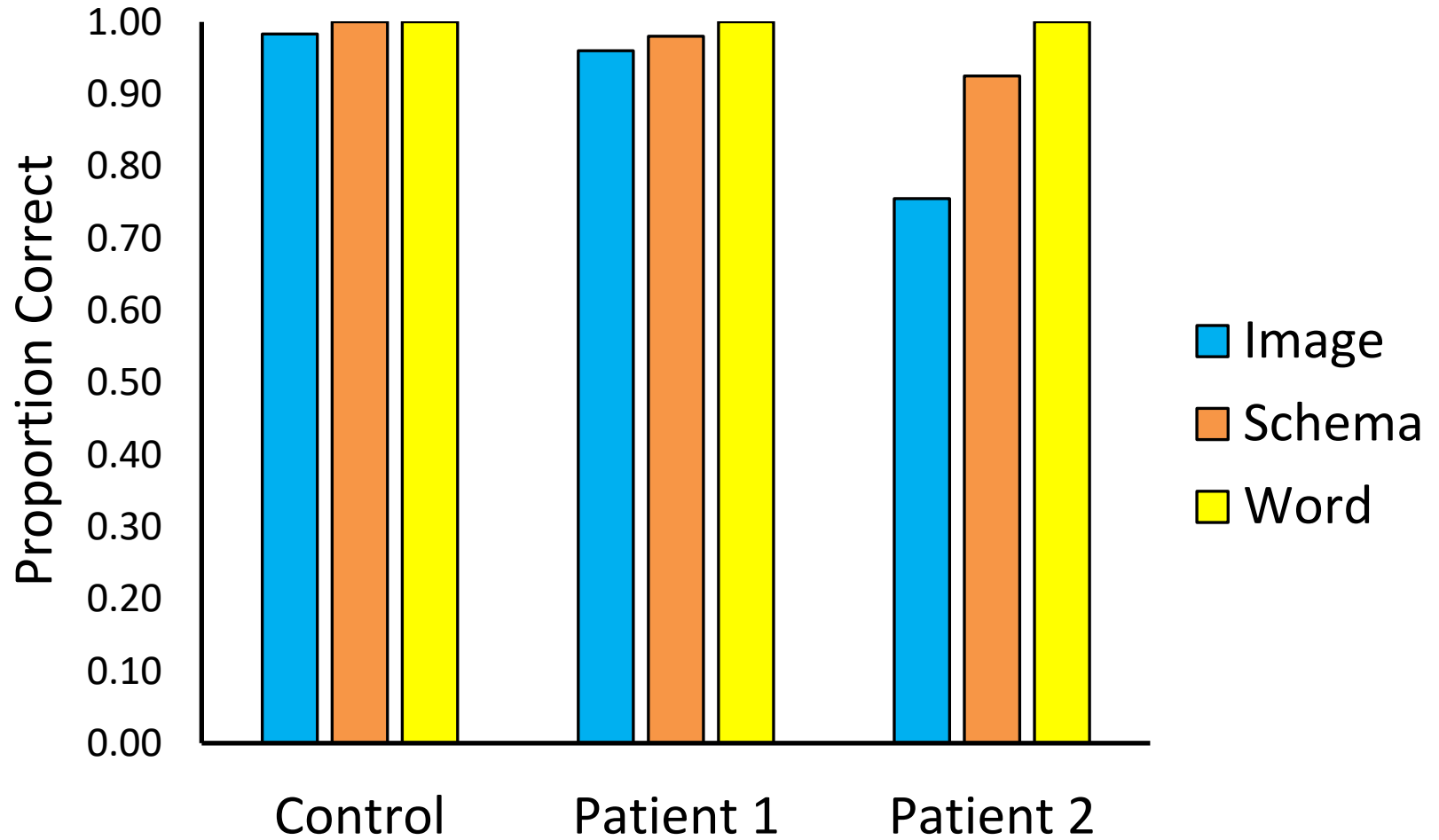
right+



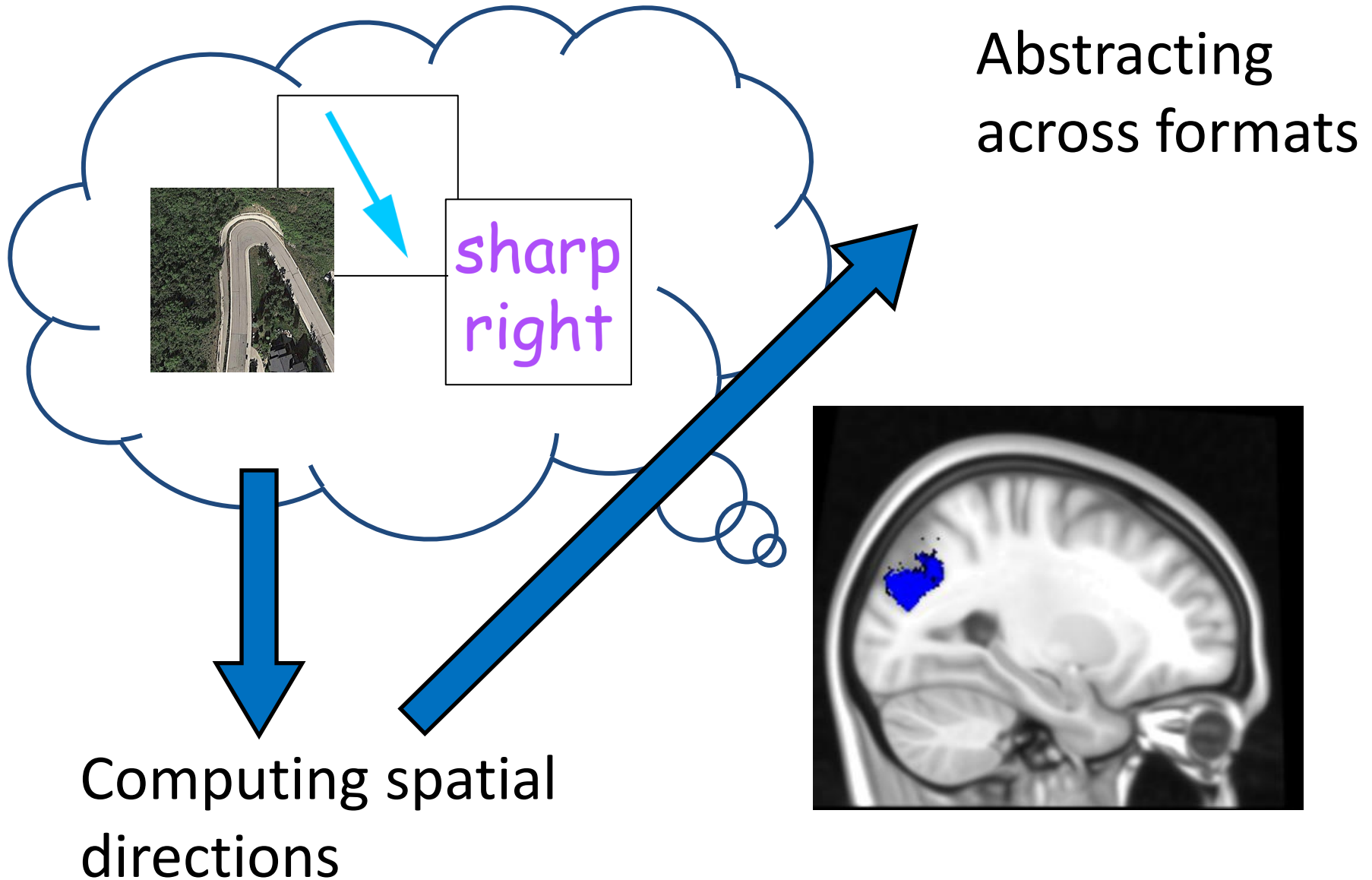
sharp
right

SAME?

Posterior Cortical Atrophy



How does the brain encode spatial directions across formats?



Our Road Map



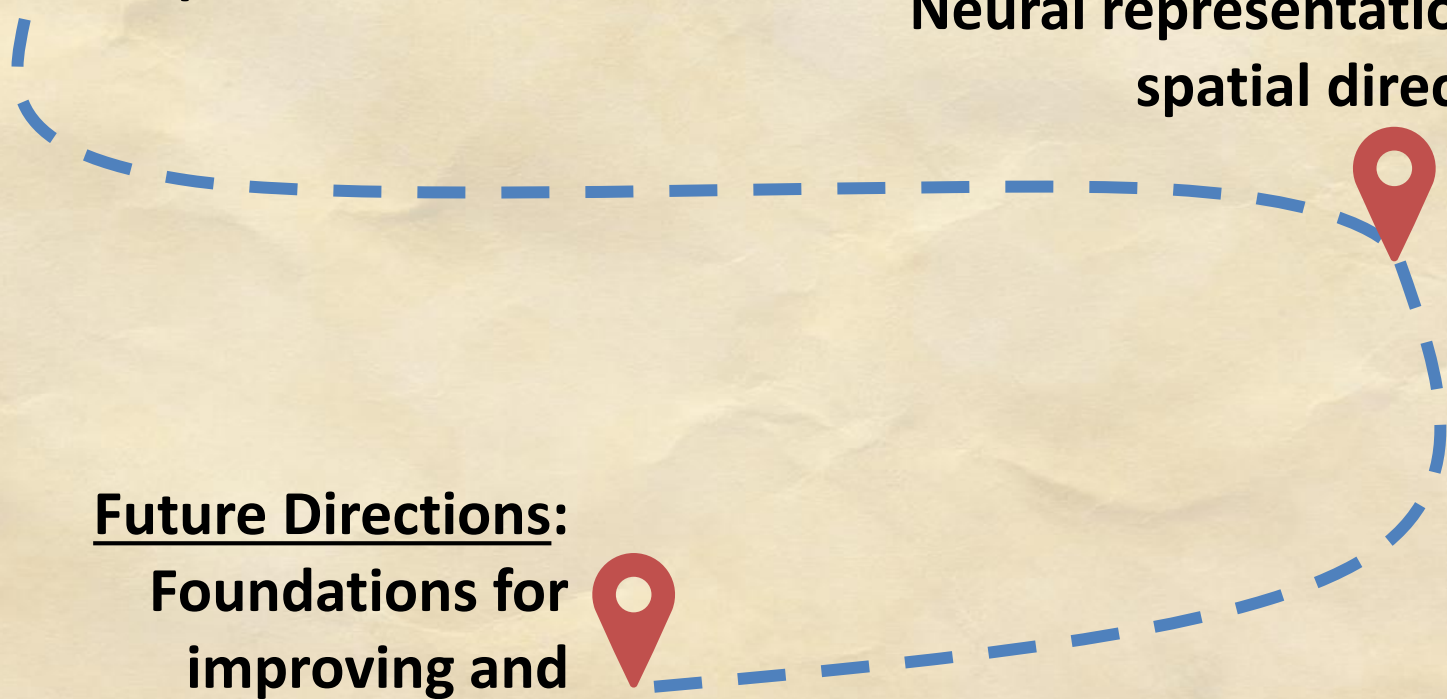
Variations in cognitive maps

Neural representations of spatial directions



Future Directions:

Foundations for improving and supporting navigation

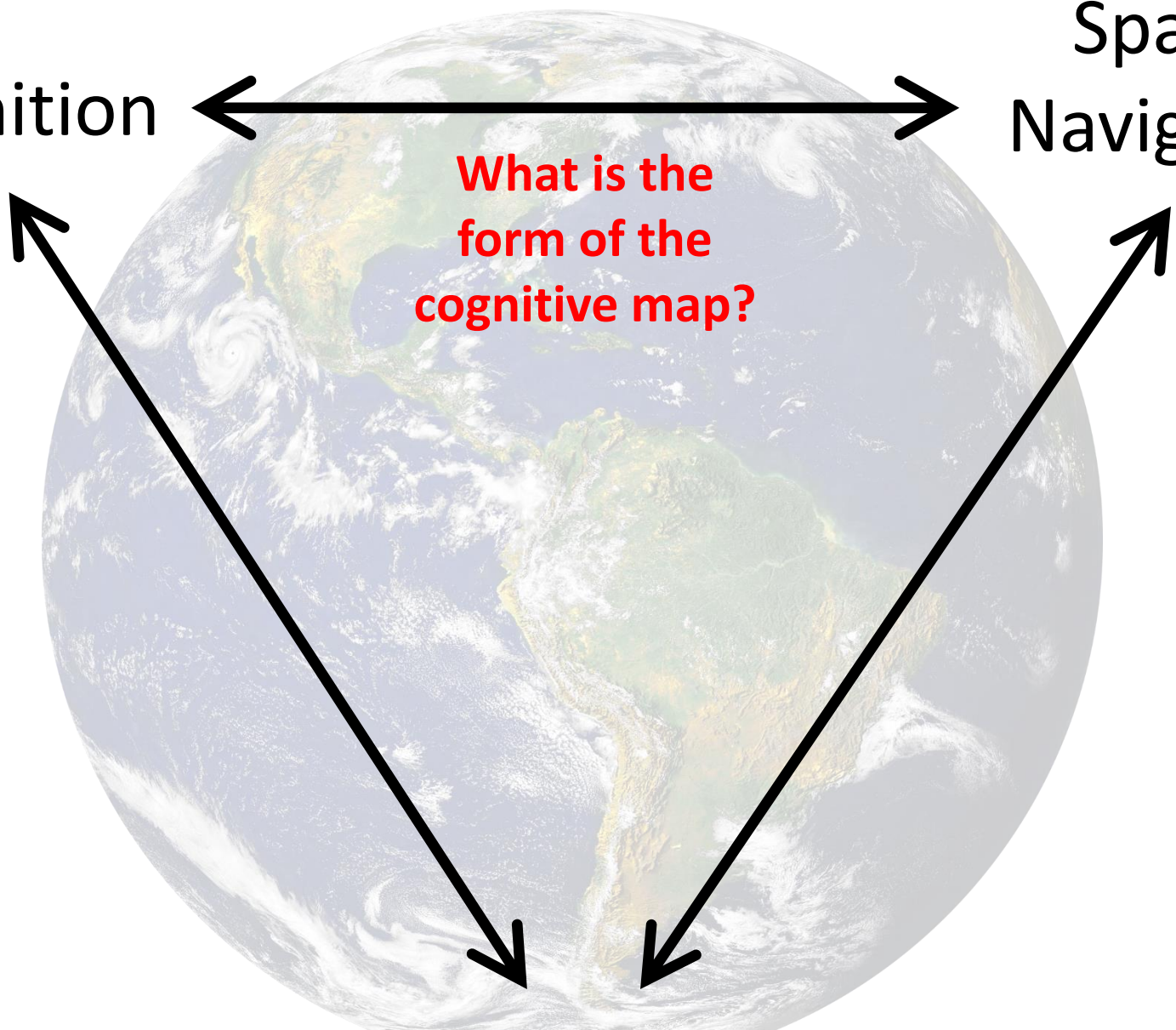


Cognition

Spatial
Navigation

What is the
form of the
cognitive map?

Neuroscience



Attention

Executive
Function

Sensory
Integration

Emotional
State

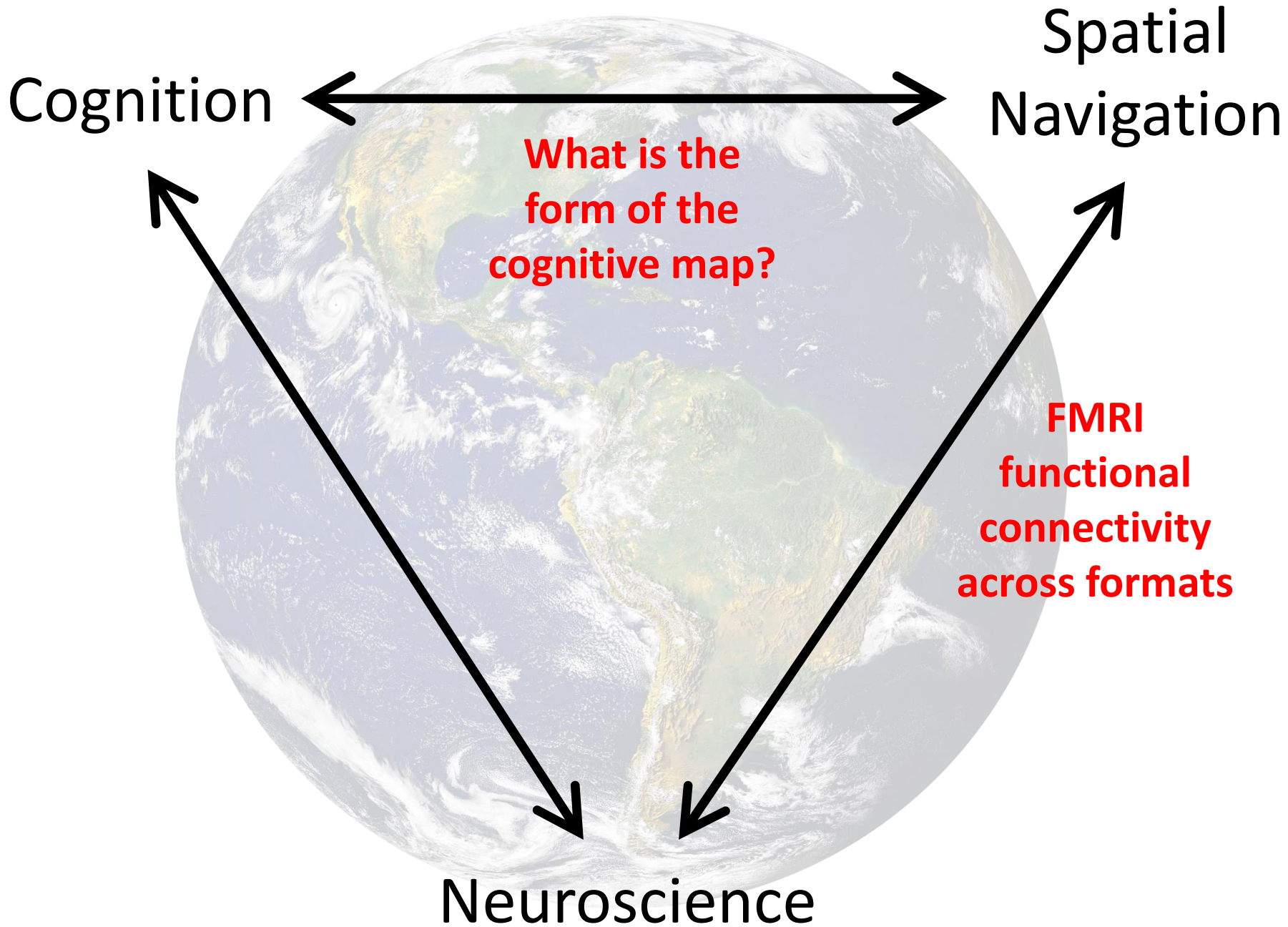
Spatial
Navigation

Goals

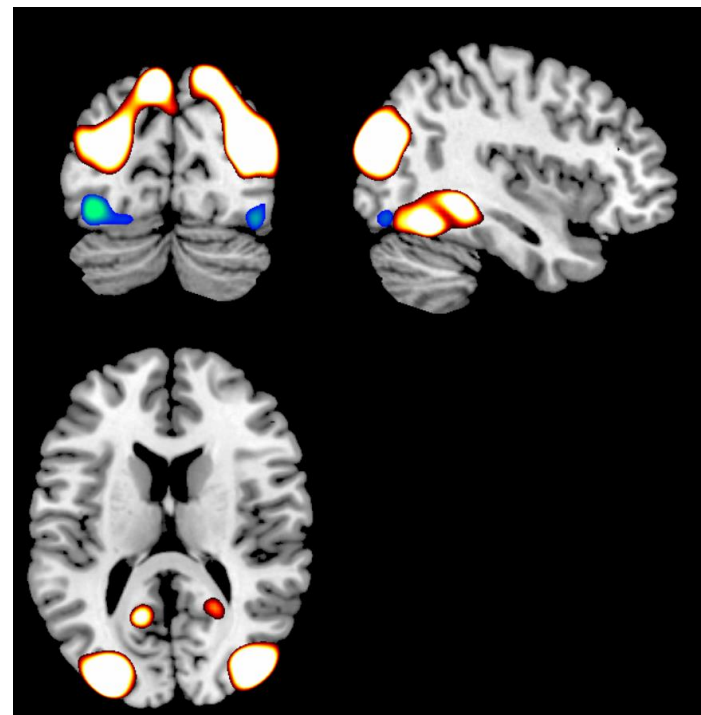
Memory

Personality
Traits

Representation

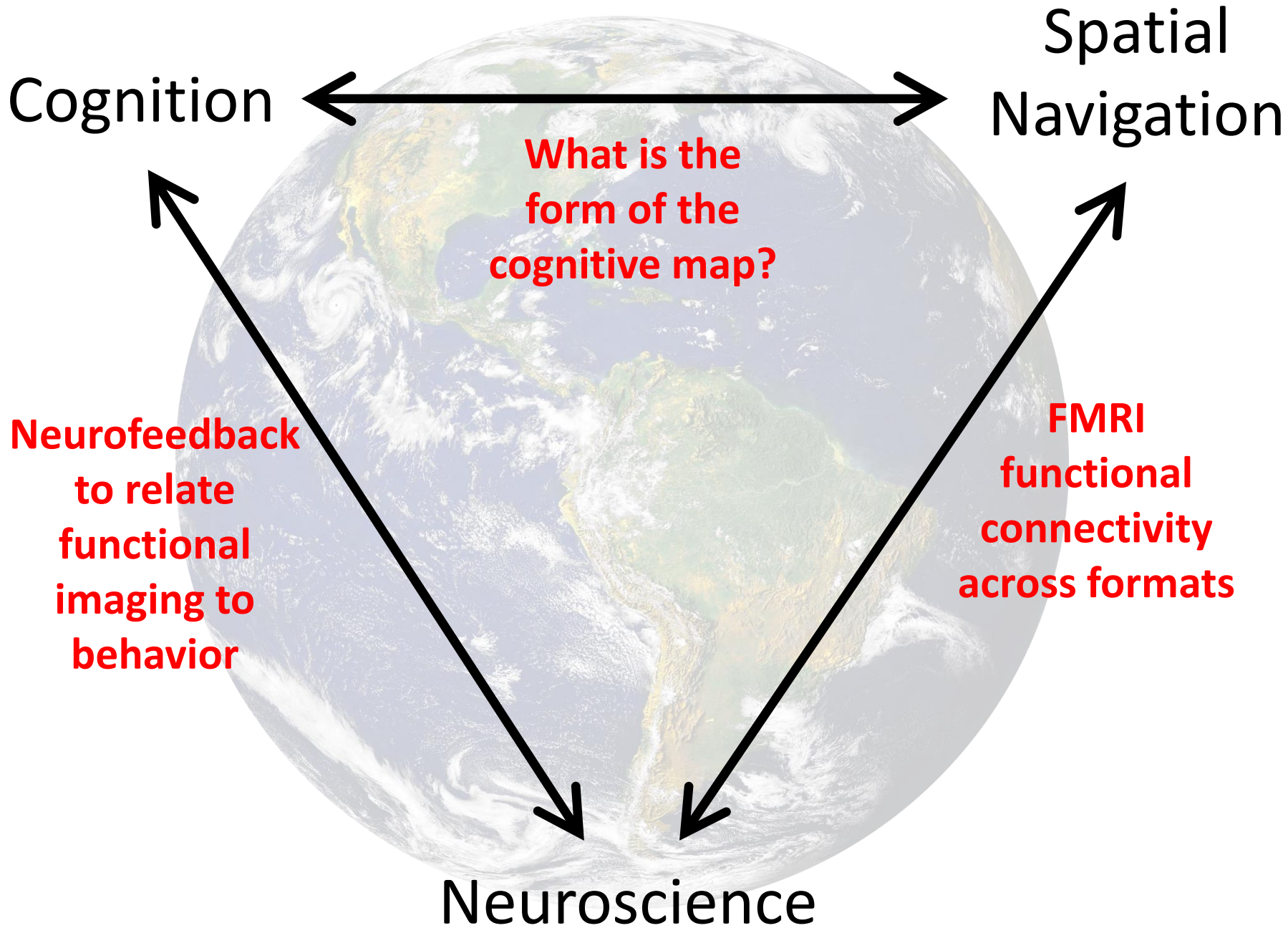


Functional connectivity: IPS as hub hypothesis

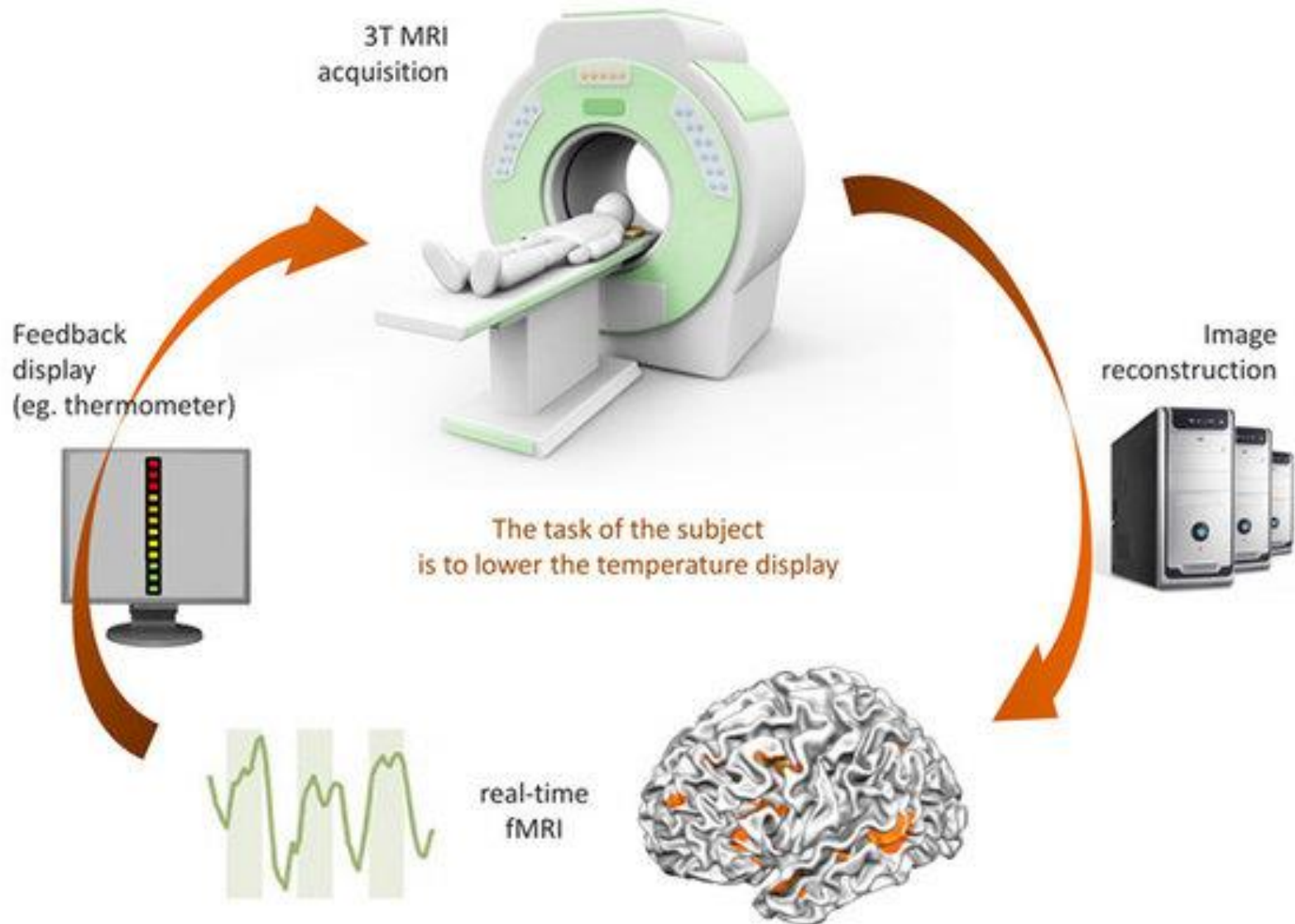


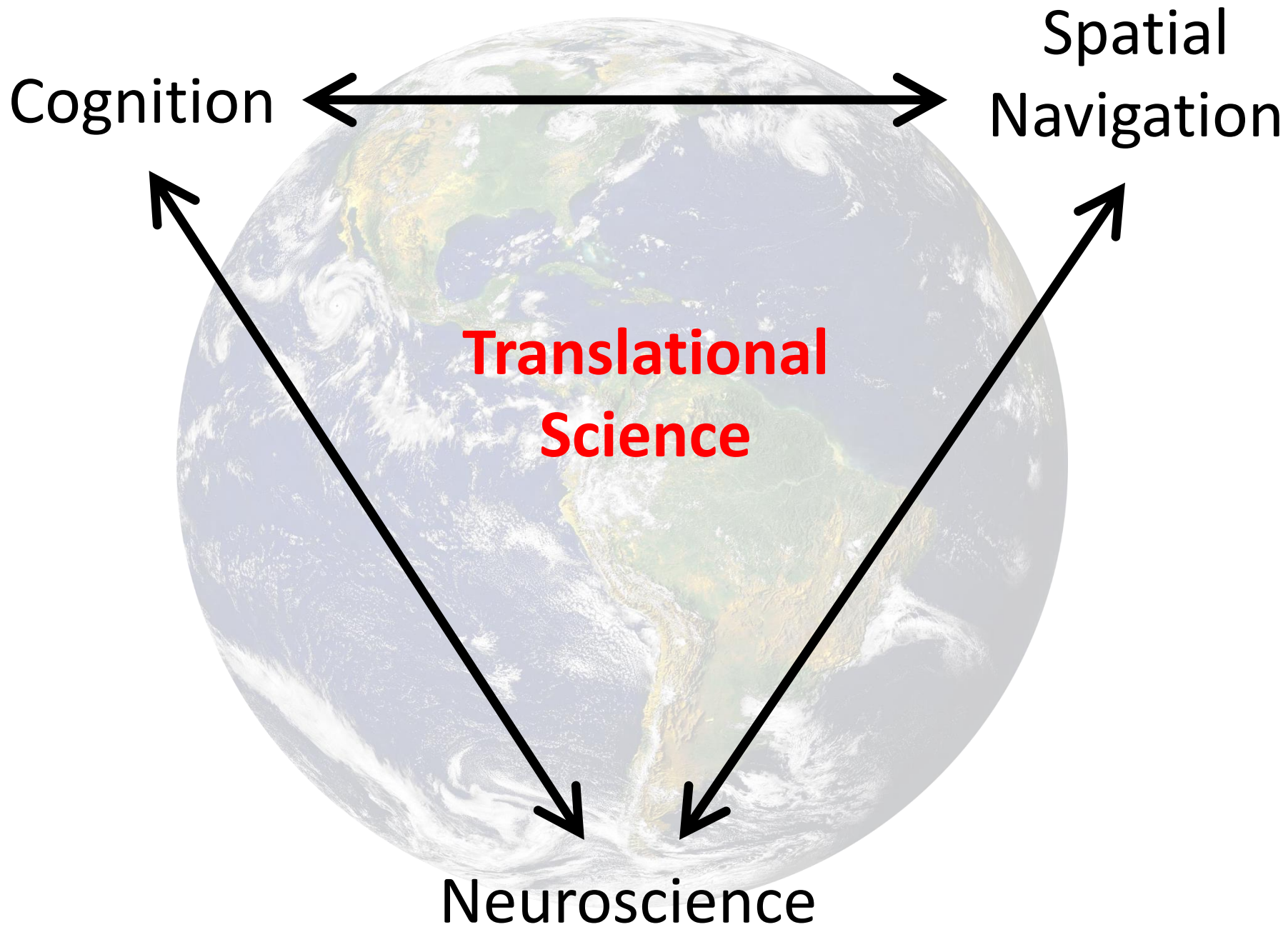
■ Images > Schemas/Words

■ Schemas > Images/Words



Real-time fMRI and Neurofeedback





Sensory Substitution in Virtual and Real World Environments

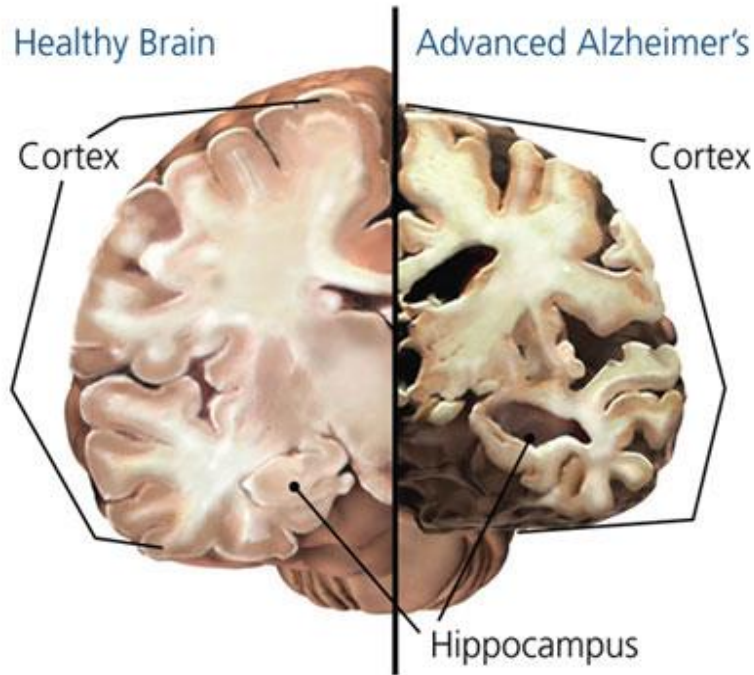


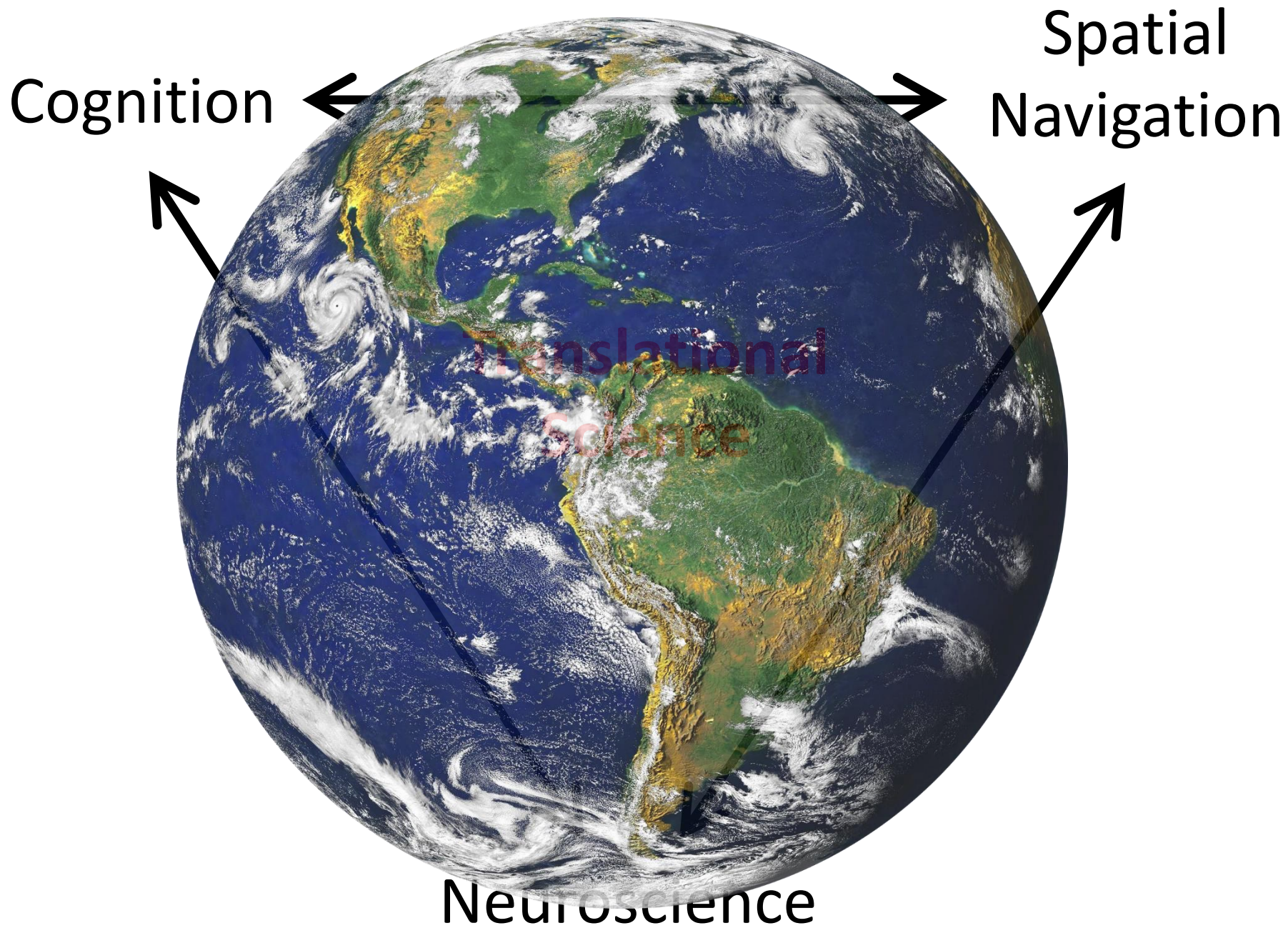
Weisberg, Badgio, & Chatterjee (2018); Weisberg, Miller, & Chatterjee (in prep)

Augmented Reality and GPS



Supporting navigation in aging populations





Acknowledgments



[A few] Collaborators

Anjan
Chatterjee

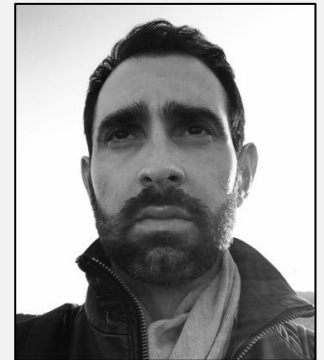


Nora
Newcombe



Russell
Epstein

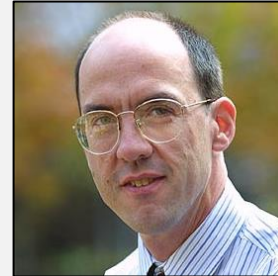
Victor
Schinazi



Steven
Marchette



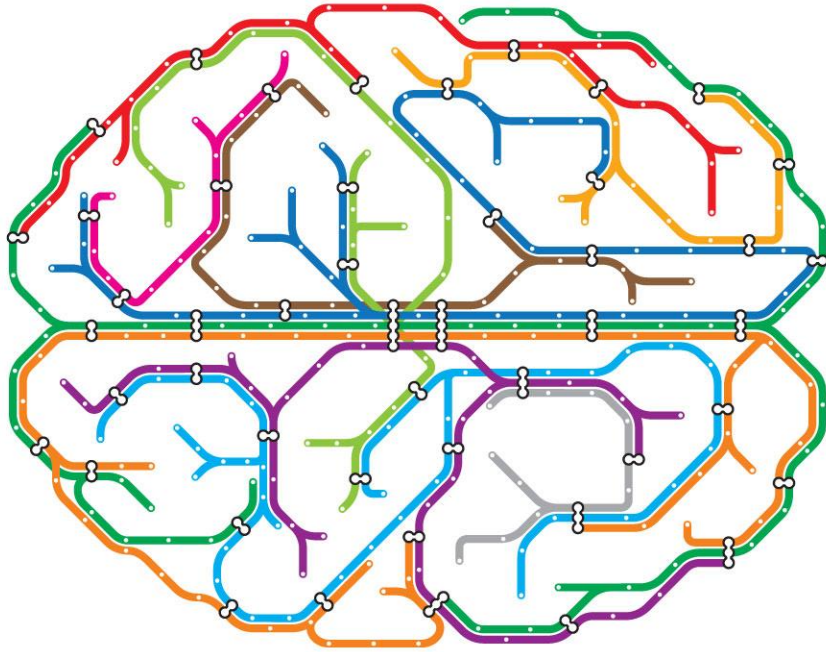
Tim
Shipley



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NSF: SBE-1041707; NIH, F32-DC-015203
NIH, R01-DC-012511





Thank you all for your attention!

Sex Differences on Virtual Silcton (Controlling for verbal IQ)

Within-Route Pointing:

d = 0.50

Between-Route Pointing:

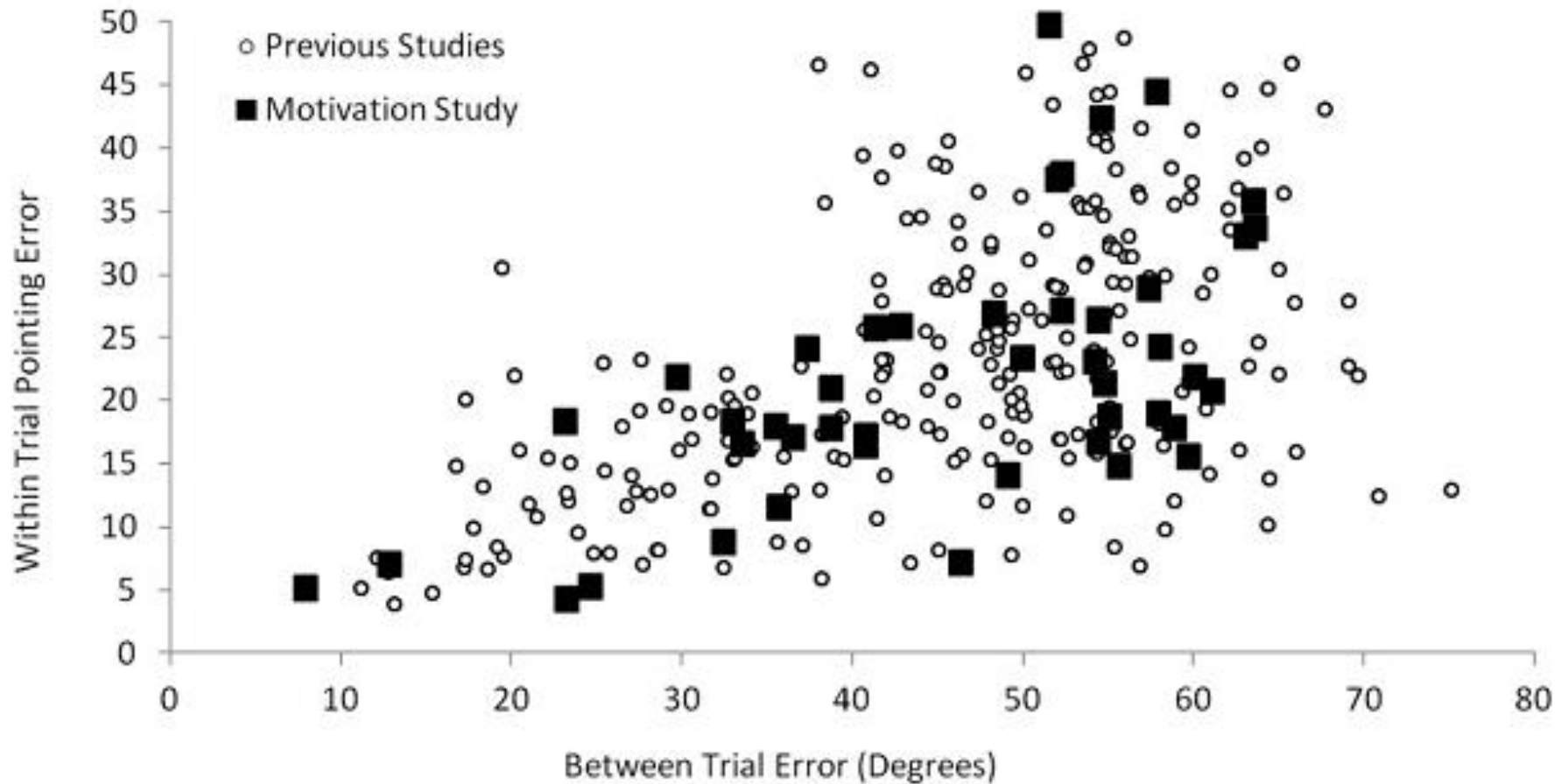
d = 0.56

SBSOD

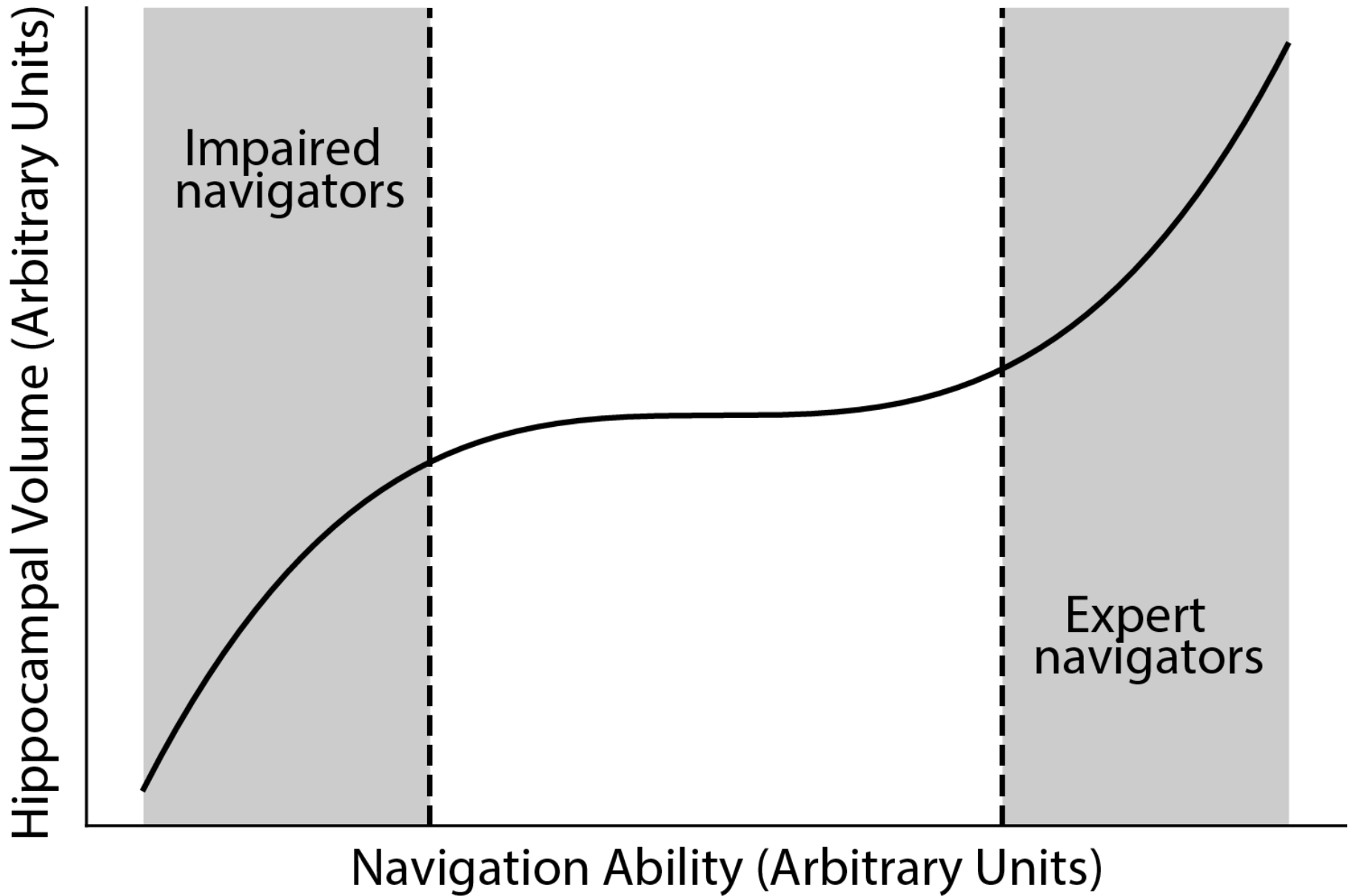
d = 0.29

Men slightly more likely to be Integrators; significantly less likely to be imprecise navigators.

Motivation

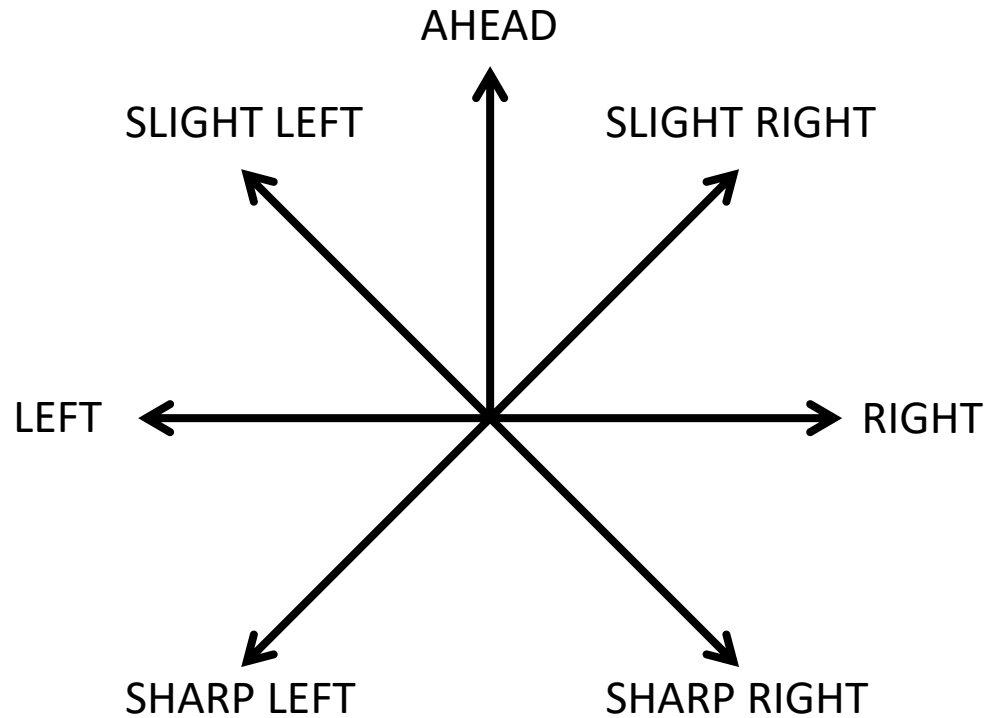


$$\chi^2(2) = 0.92, p = .63$$



Stimuli Generation

7 spatial directions (after Klippel & Montello, 2007):



Behavioral Method

N = 48 right-handed, English-speaking undergrads

Procedure

Pre-registered at the Open Science Framework <https://osf.io/djwfa/>

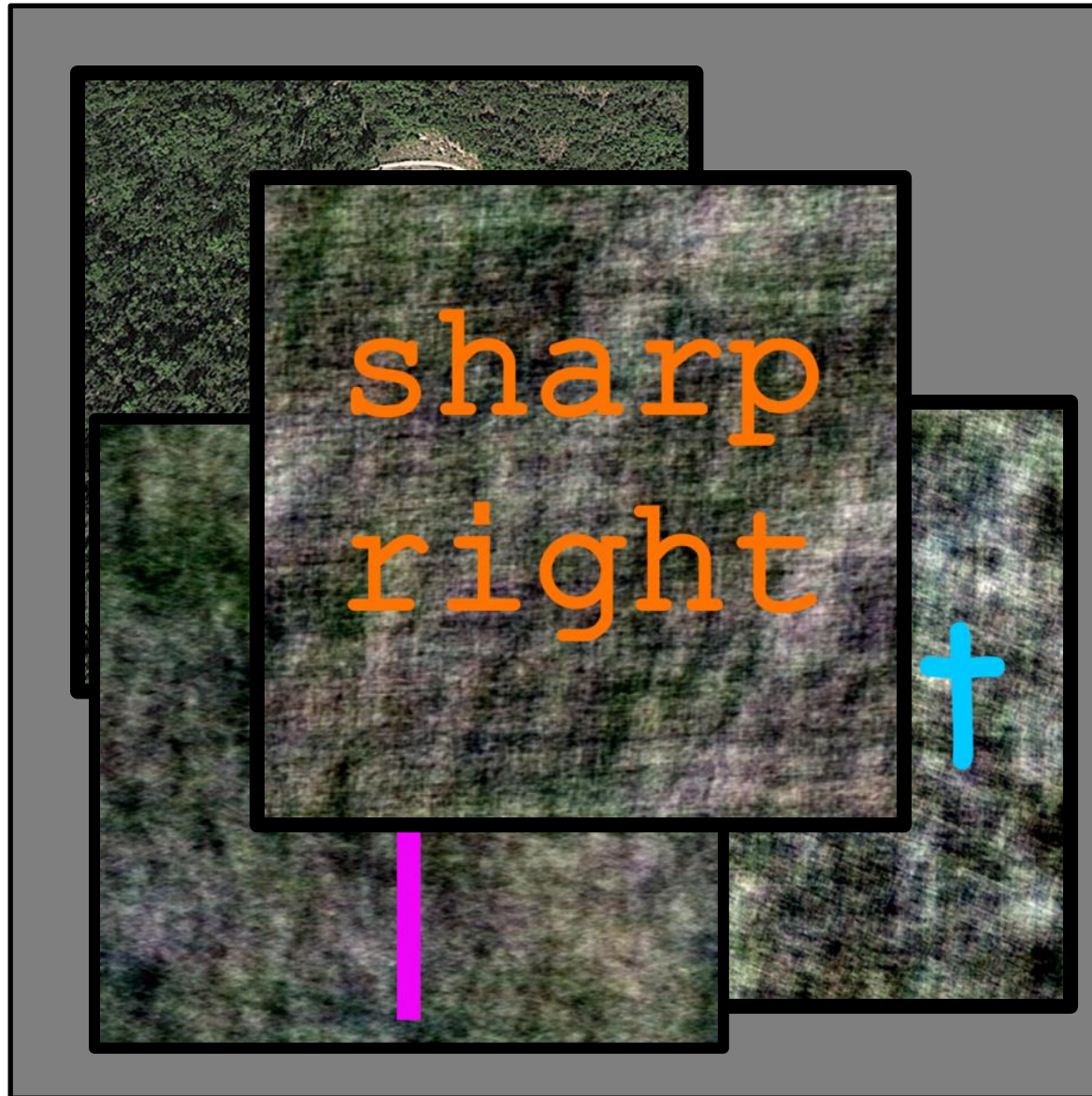
Rolling one-back task

Continuous Carryover Trial Sequence (Aguirre, 2007)

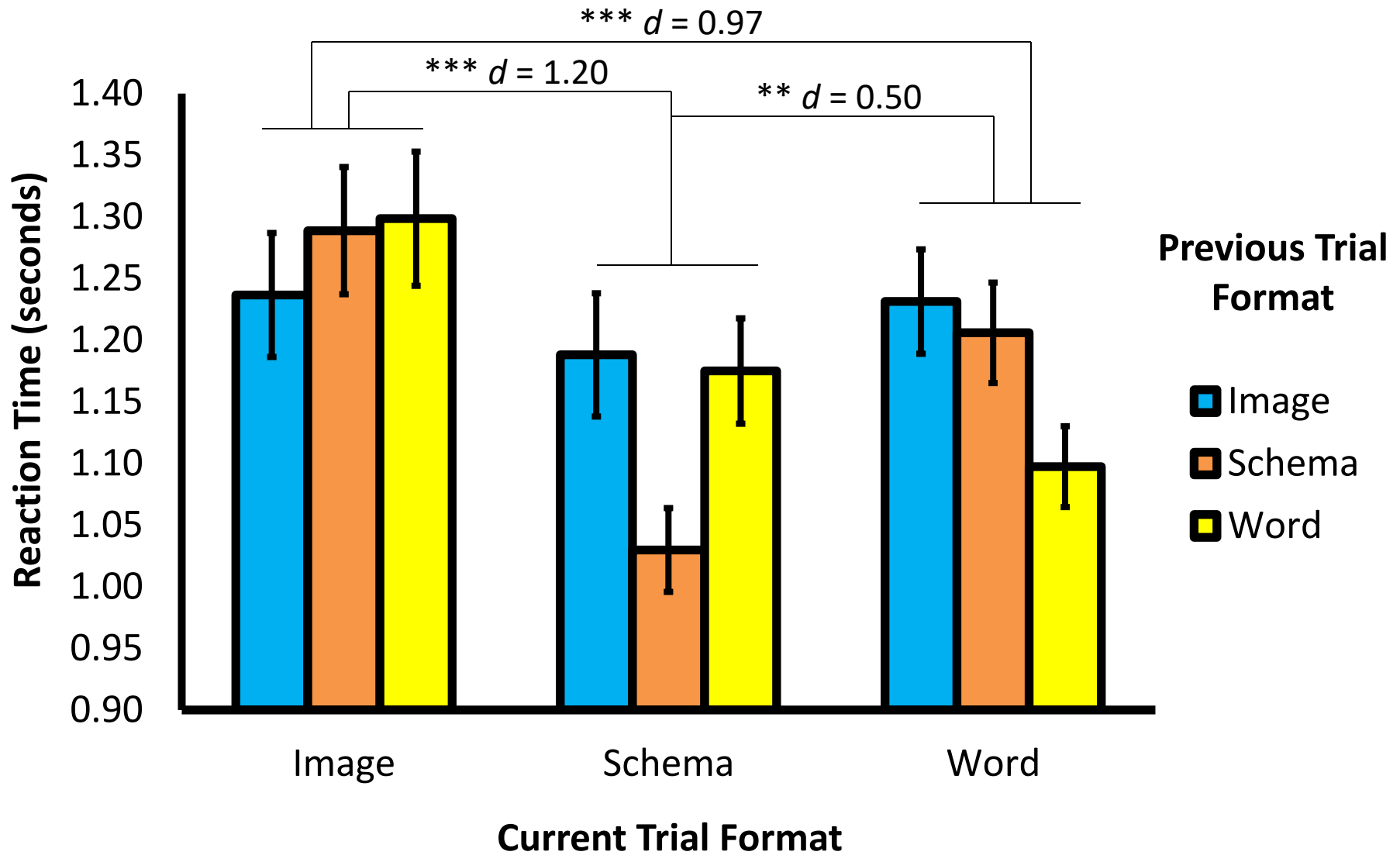
Each trial type is preceded by every other trial type

441 total trials

Measured reaction time / accuracy



SAME or DIFF

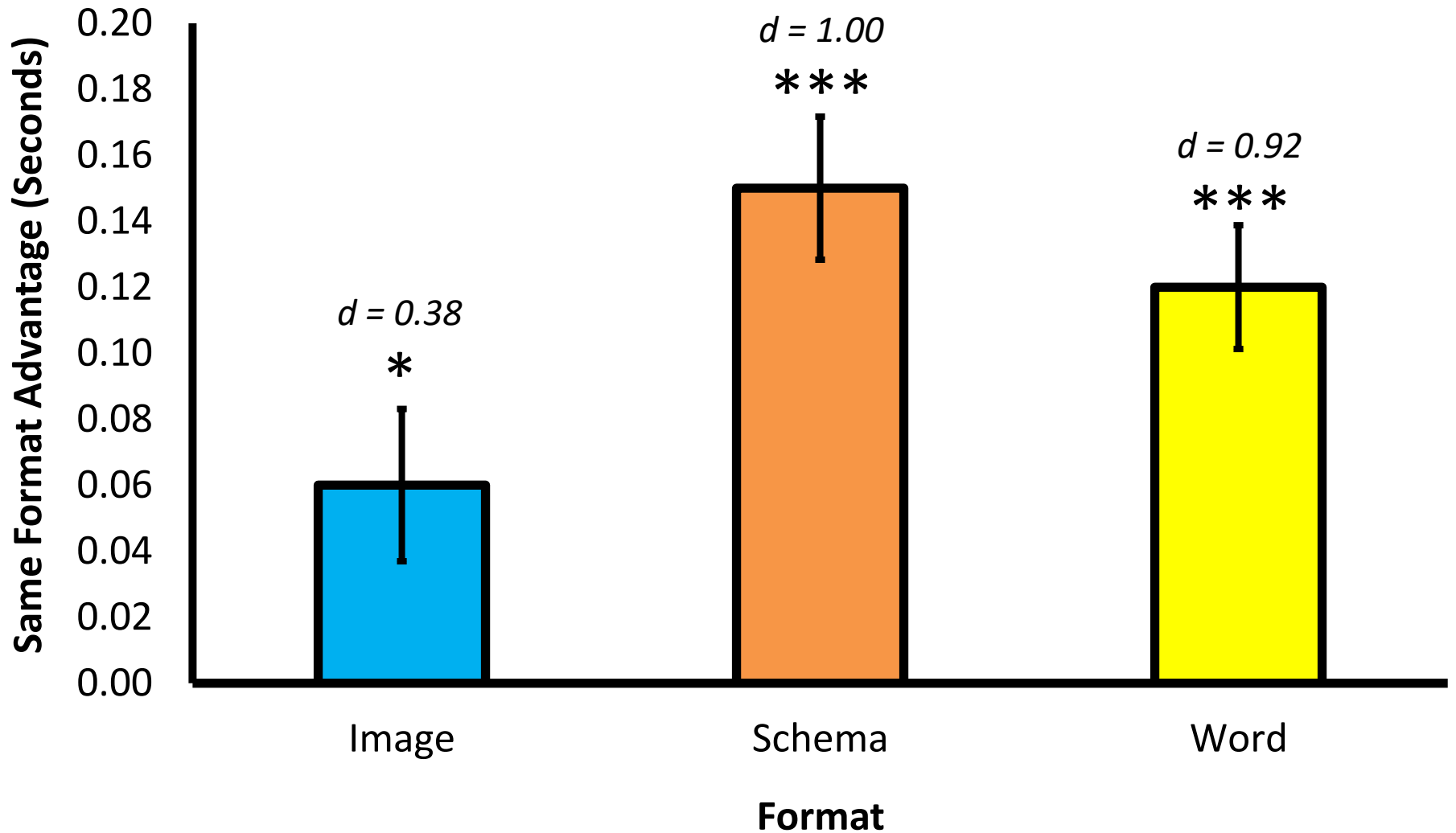


** $p < .01$, *** $p < .001$

Error bars = \pm SEM

Weisberg, Marchette, & Chatterjee (in revision), *J Neuro*

Same-format advantage greatest in schemas, words



* $p < .05$, *** $p < .001$

Error bars = \pm SEM

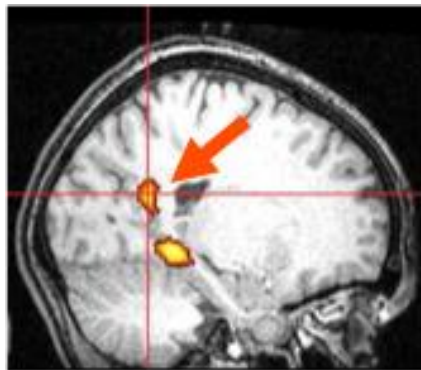
Weisberg, Marchette, & Chatterjee (in revision), *J Neuro*

Visual Scene Regions



PPA

parahippocampal
place area



RSC

retrosplenial
complex

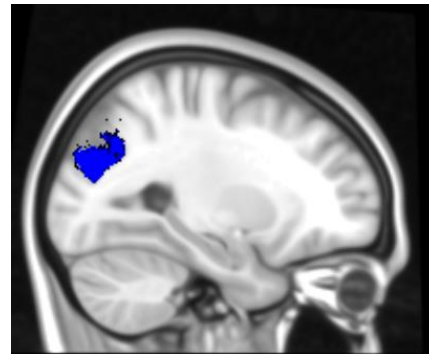


OPA

occipital place
area

Functionally defined,
anatomically constrained
Julian et al. (2012)

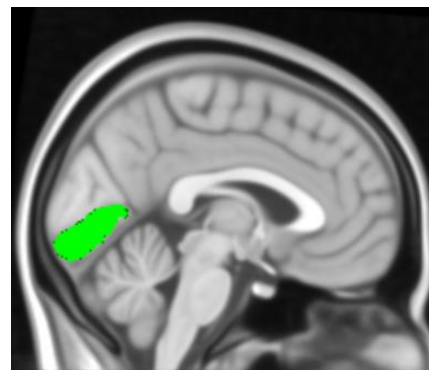
Spatial Direction Region



IPS

intraparietal
sulcus

Low Level Vision

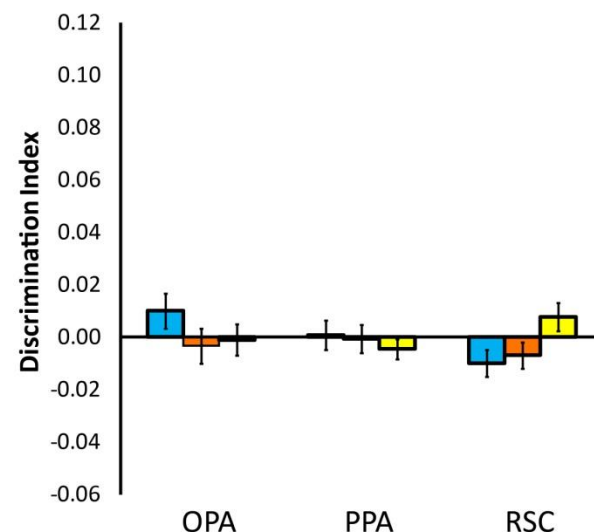
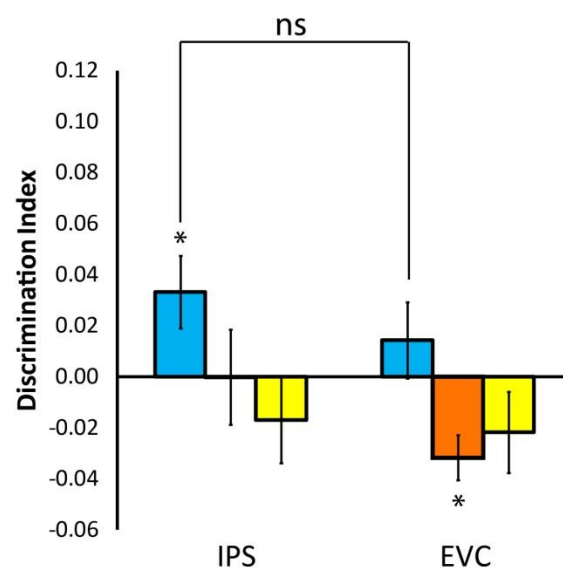
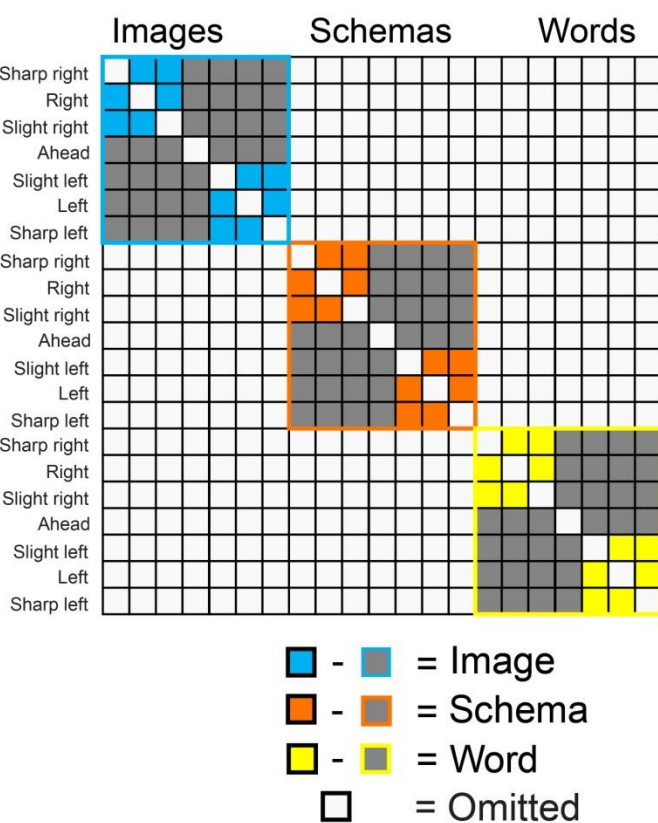


EVC

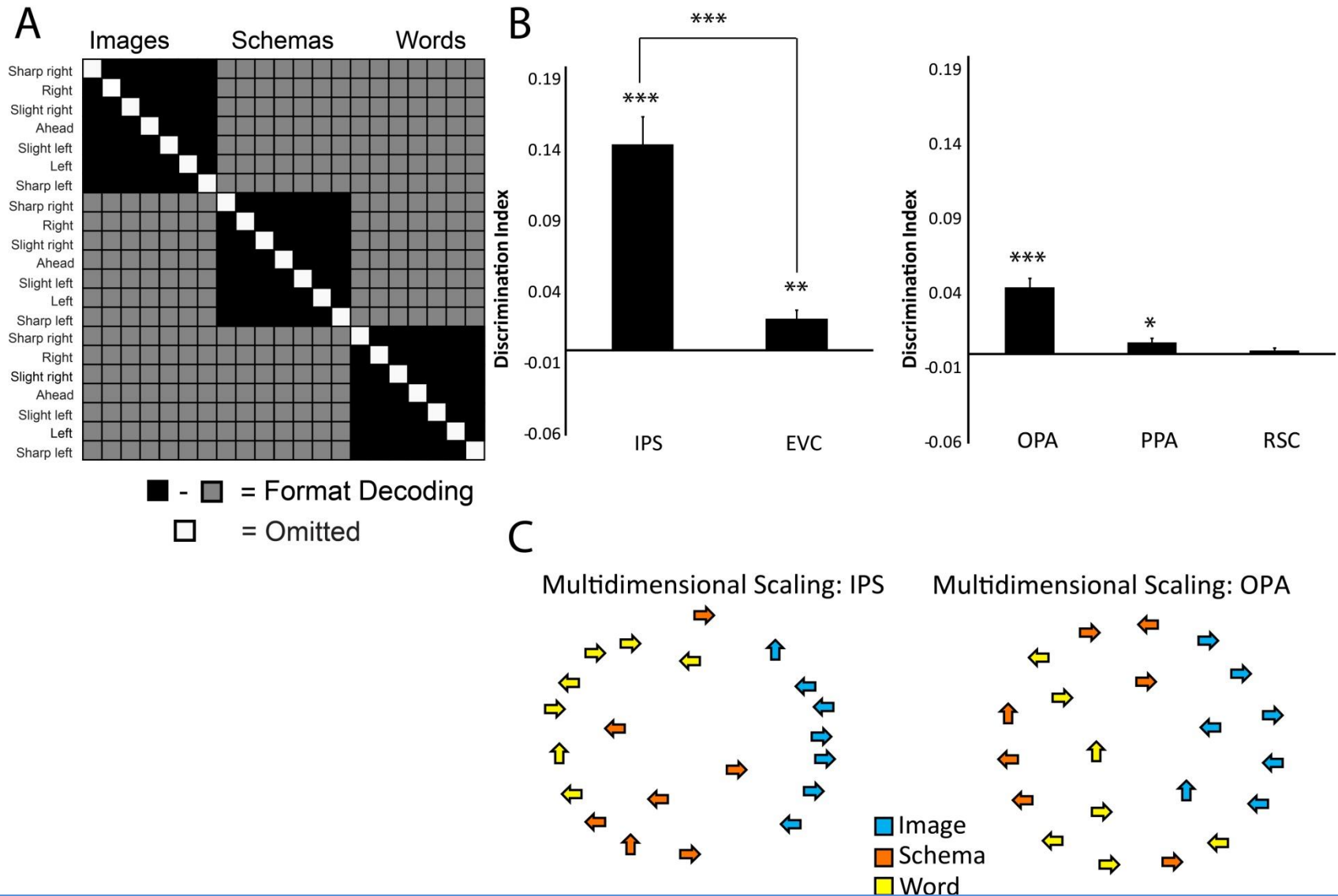
early visual
cortex

Anatomically defined with
probabilistic maps
Wang et al., (2015)

Categorical spatial direction decoding



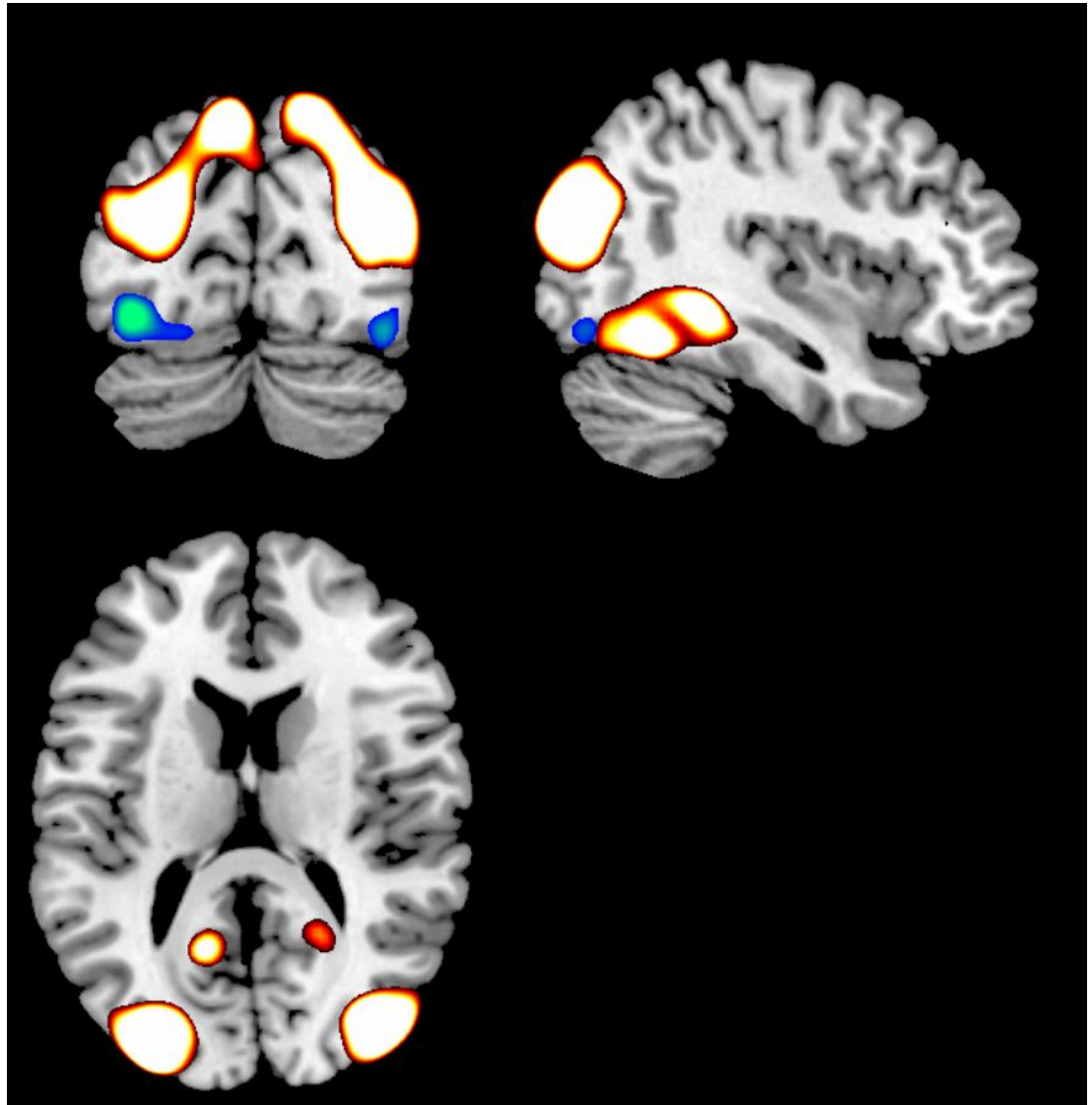
Format Decoding



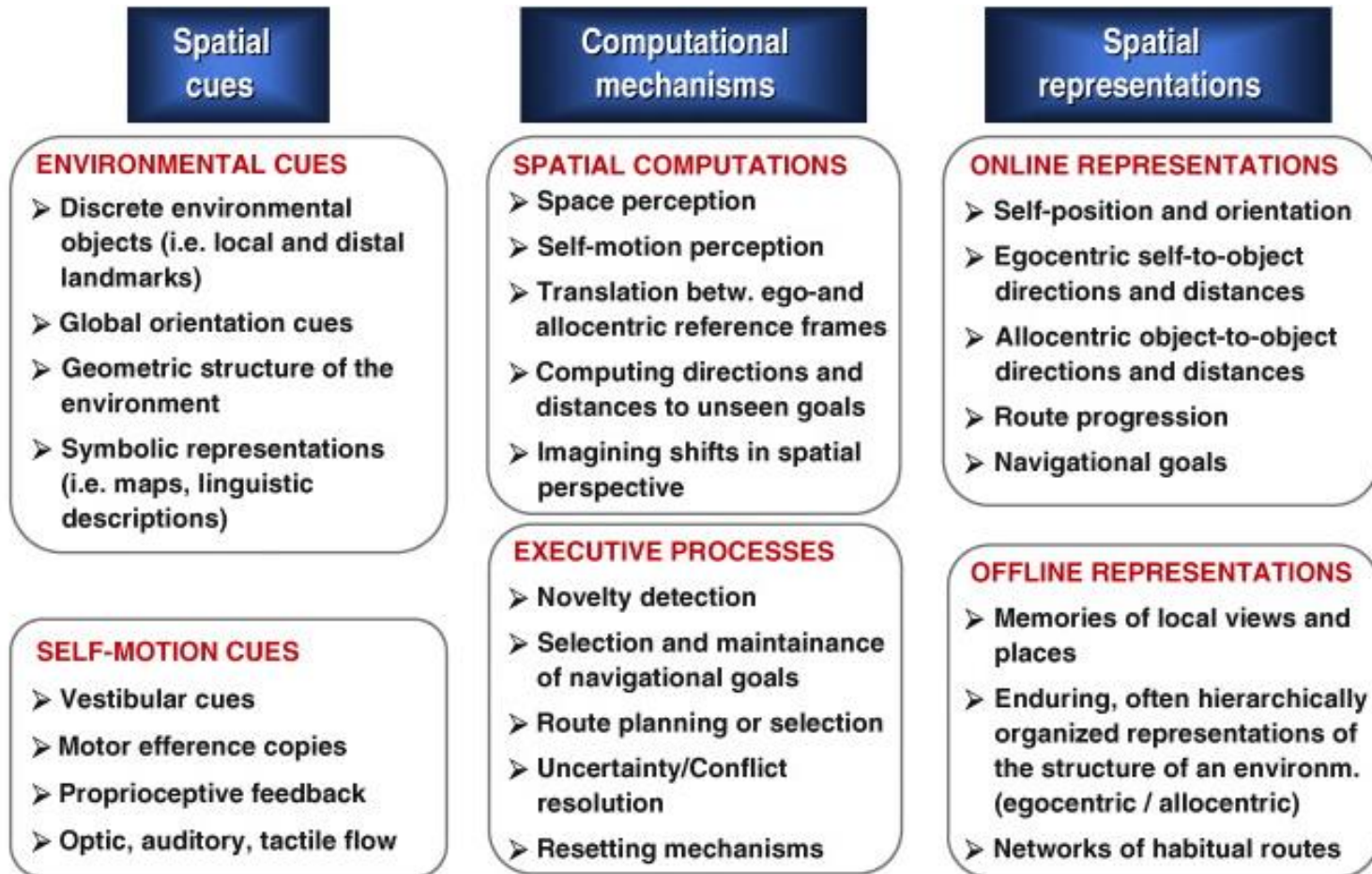
Format Decoding Searchlight

 Schemas vs. Words

 Images vs. Other



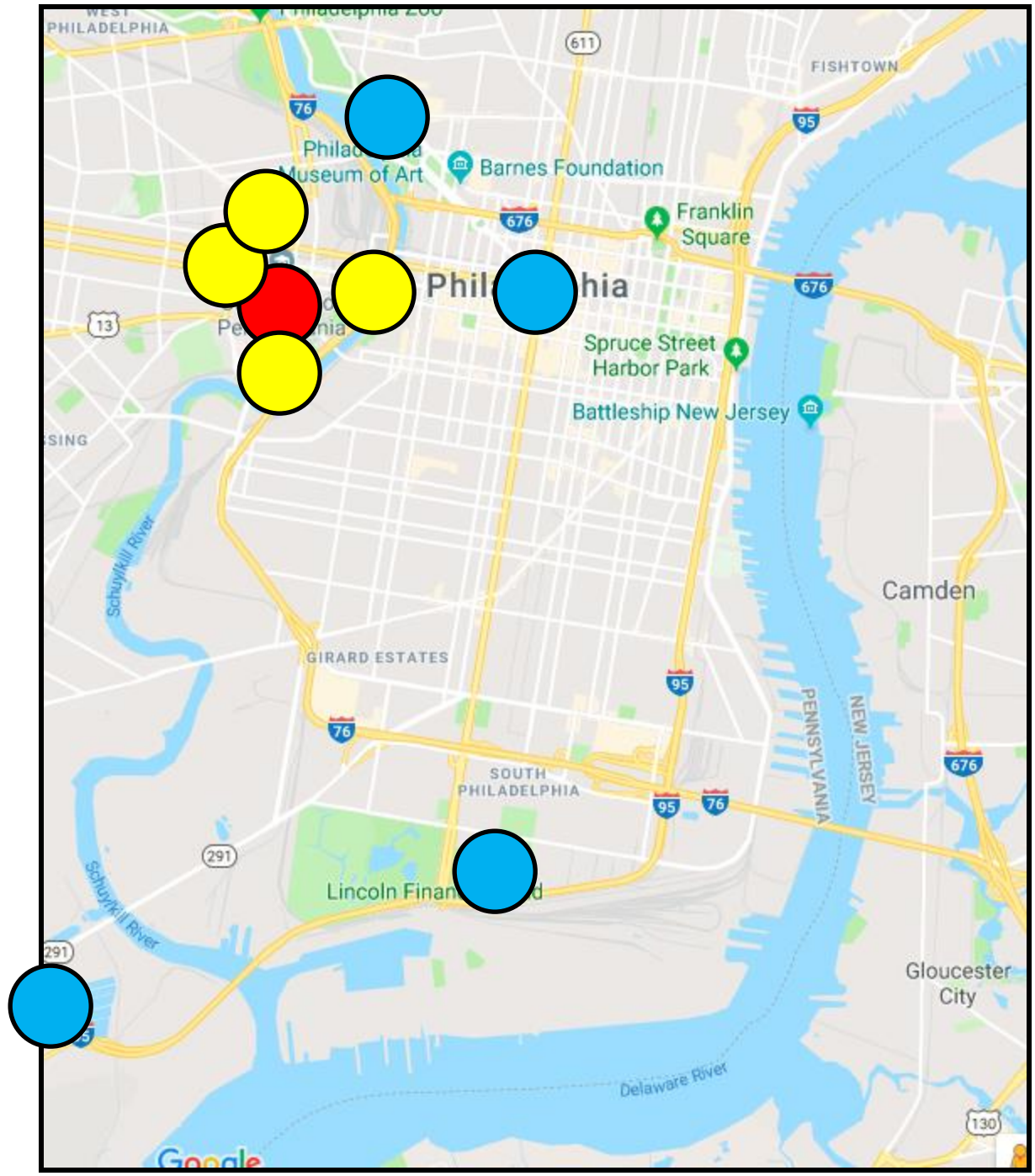
Variability across individuals



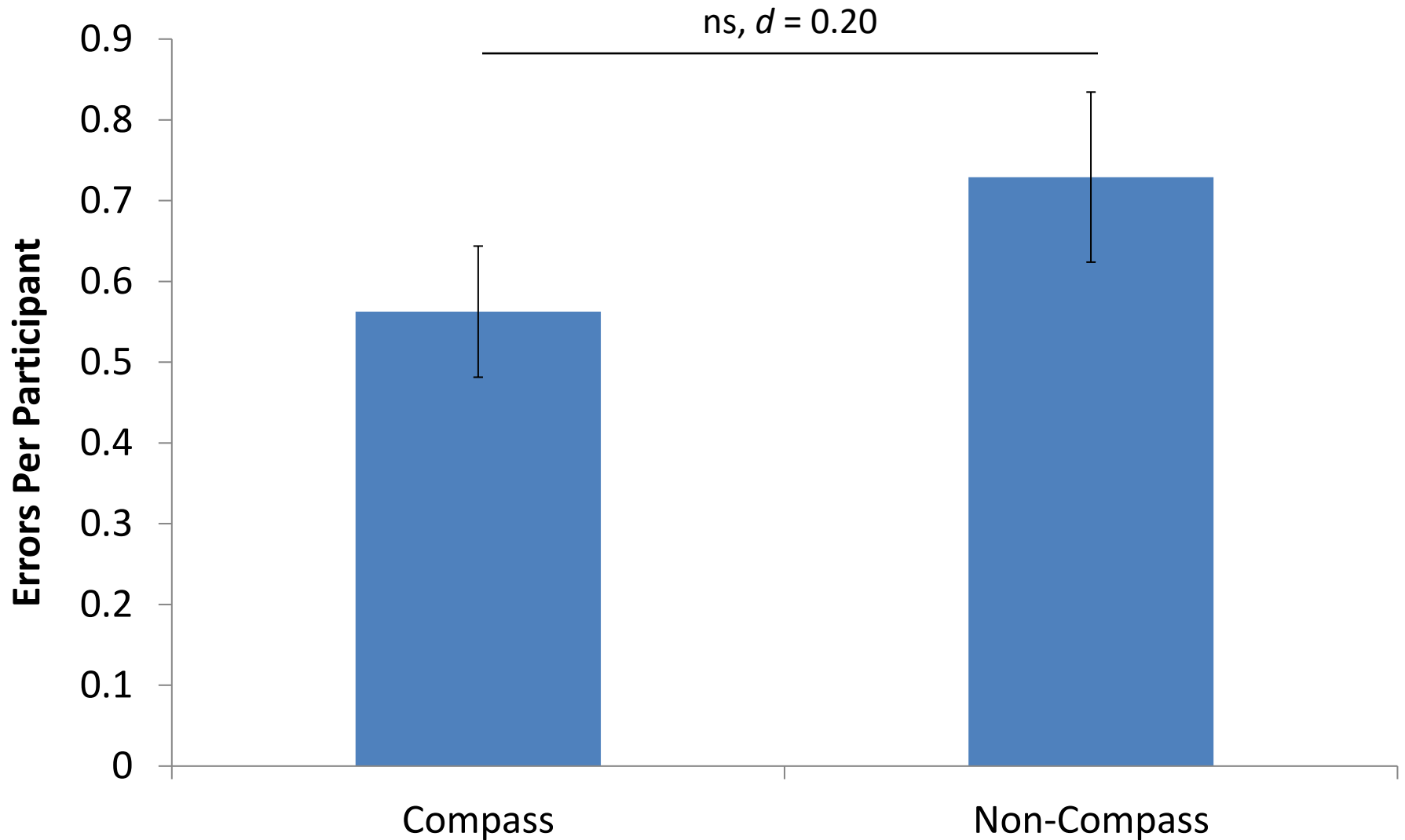
 Hospital

 External Landmarks (Penn)

 External Landmarks (Philly)



Route Reversal Errors

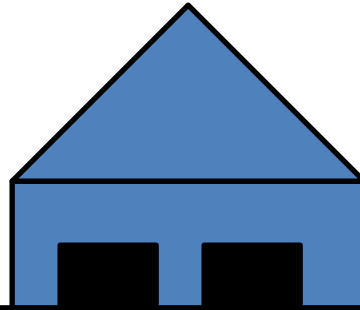
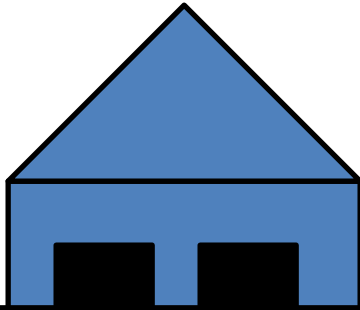


Night 1

Night 2

Total Energy
(Univariate)

e 1

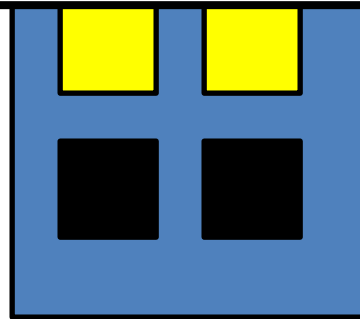
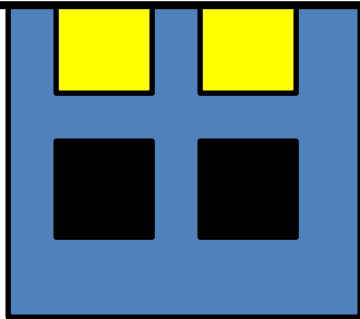


=



Number of lights do not distinguish Time 1 and Time 2.

Time



Night 1

Night 2

Energy Pattern
(Multivariate)

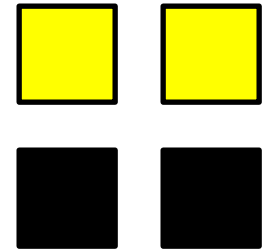
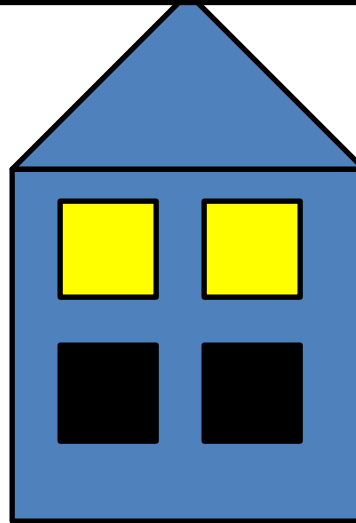
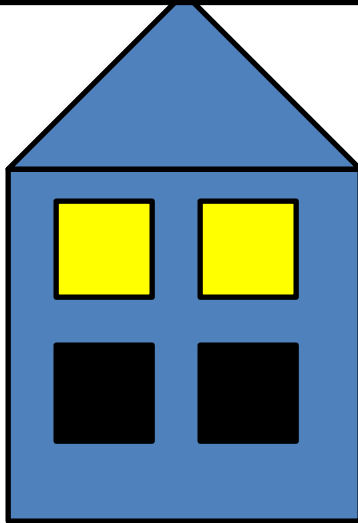
Dimmer

Light patterns
distinguish Dinner and
Bed time.



≠

Beichtanze



Spatial Direction Decoding Across Formats

