Spatial navigation in humans

Recap: navigation strategies and spatial representations

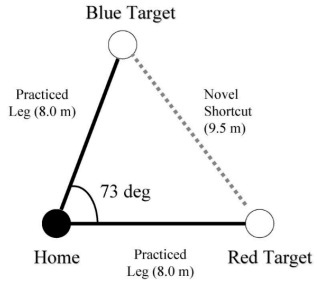
Spatial navigation with immersive virtual reality (VENLab)
- Do we construct a metric cognitive map?
- Importance of visual landmarks in navigation!
- Representing space with a "labeled graph"?
- Role of decision-making when exploring new spaces

To what extent are various brain areas engaged during different types of navigation behavior?

Spatial navigation with immersive virtual reality

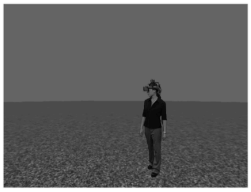
- immersive virtual reality gives subjects a realistic interactive environment
- subject moves freely in a 12m x 12m room
- 3D location and orientation is tracked continuously, visual input updated
- cues: stereo/motion vision, proprioception, vestibular

Do humans combine traveled routes into a survey representation that permits metric navigation in the environment?



- subjects learn two paths (home to blue, home to red) to *remembered target locations*
- after training, walk novel shortcut between targets
- **if subjects represent *metric* information about distances and angles, they should be able to accurately walk the novel shortcut**
- **if subjects rely on *landmarks*, expect more accurate performance for forest scene**

- poor performance for desert **(questions metric map)**
- good performance for forest **(landmarks important!)**

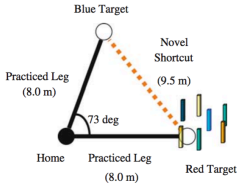


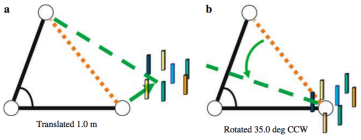
desert

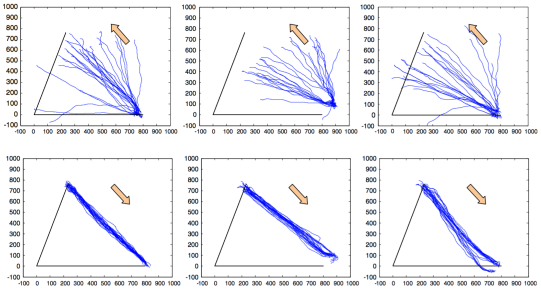
forest

Further exploring the role of landmarks to guide navigation

- same task as before
- virtual world: desert with 7 posts
- after training, translate or rotate posts near red target, *on some trials*







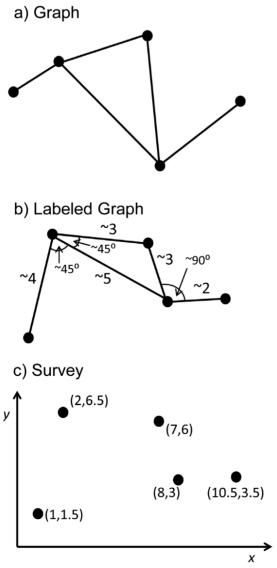
no change **posts translated** **posts rotated**

- landmarks near start of shortcut help initial bearing, but then large errors accumulate
- landmarks at end of shortcut act like "beacons" for navigation

Also suggests that our "survey knowledge" is not accurate

Spatial knowledge based on labeled graphs

Chrastil & Warren (2014)

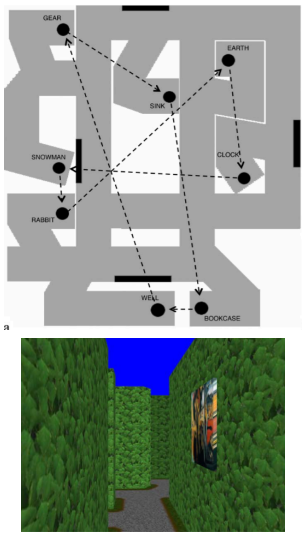


Graph representations of spatial knowledge

Graph in (a) only captures connectivity
- nodes represent places visited
- edges represent connectivity (routes)
- enables detours

Labeled graph in (b) includes metric info
- connections have distances, nodes have angles between paths that meet at node
- may be less precise than survey knowledge
- good enough for finding efficient routes or detours, novel shortcuts

Exploring sources of spatial knowledge



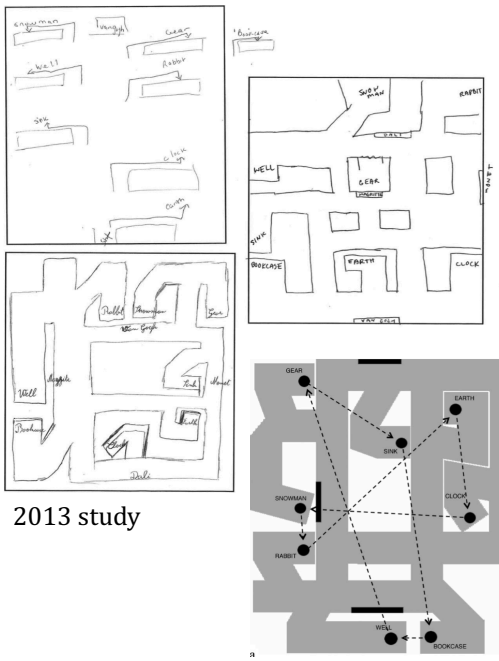
Chrastil & Warren (2013, 2014)

Subjects explored maze for 10 mins to learn locations of 8 objects
- *active vs. passive* (free vs. guided)

Different cue combinations:
- visual + vestibular + podokinetic (walk)
- visual + vestibular (wheelchair)
- visual (video)

Testing (2013 study):
- walk along novel shortcut between pair of objects, using *remembered* locations (*as the crow flies*, with no visual input)
- *survey knowledge* needed for this task

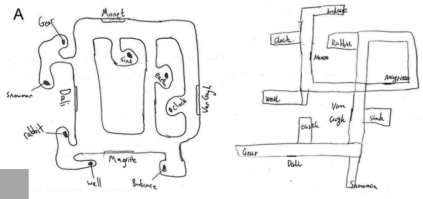
2014 study:
- no visual + vestibular condition
- walk shortest path within maze corridors
- occasional barriers to force detours
- *route/graph knowledge* needed for this task

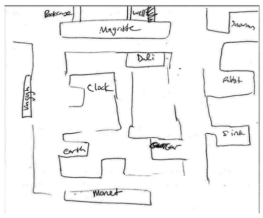


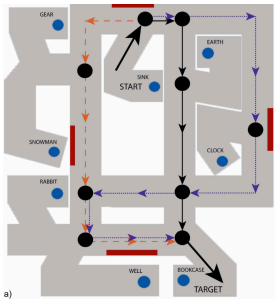
2013 study

After completing experiment, subjects given list of objects and paintings, asked to sketch a map

2014 study

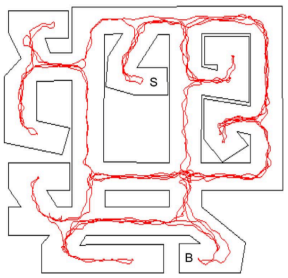


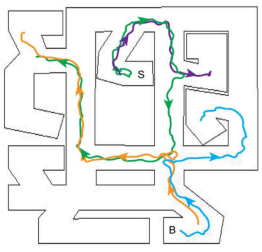




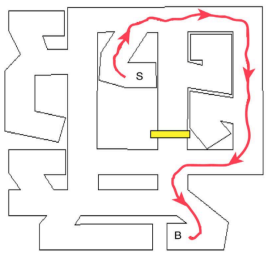
After training, walk between two learned objects using shortest path possible

40% trials: barrier appears, requiring detour from plan





Experienced paths between sink and bookcase



During test, walked the shortest *novel path* between sink & bookcase

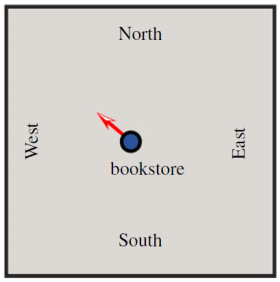
Para-hippocampal place area

PPA

Identifies landmarks

Retrosplenial complex

RSC

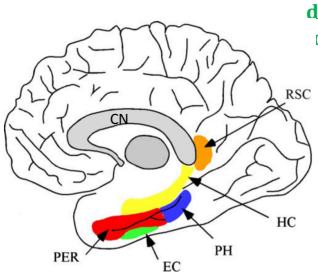


Uses landmarks to determine the current location and direction

Medial temporal lobe Hippocampus

MTL

Encodes a cognitive map that represents landmarks and goals in terms of coordinates in allocentric space



To what extent are these brain areas engaged during different types of navigation behavior?

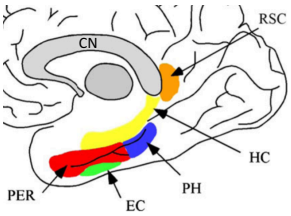
Neural evidence supports a novel framework for spatial navigation
Elizabeth Chrastil (2013)

I turned 30° and walked 5 m from my initial heading and location
(EC, HC)

Turn left at the bank
(HC, CN)

City Hall is at the corner of Main and Broadway
(HC)

I turn right on 5th street, then left on Broadway, then go four blocks, and City Hall is on the left
(HC, RSC)



I'm at the bank
(PH)

Turning right at the bank takes me to the market, turning left takes me home
(HC, CN)

Down this street, first I will encounter the bank, then the market, then the school
(HC)

I'm at the bank, which is on the west side of town, near the fire station
(PH, HC, EC, RSC)

I will need to make a turn at the bank
(PH)