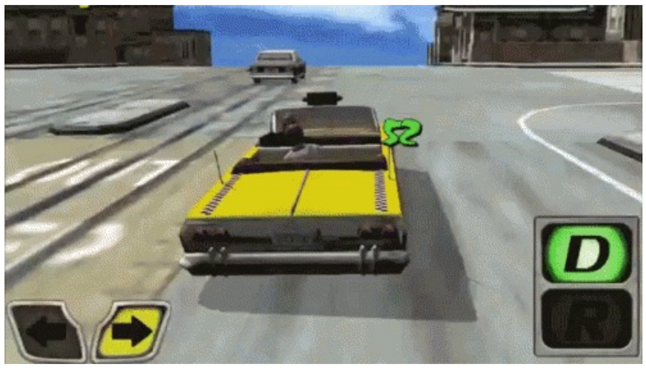
PSYC 365 Class 18:
The hippocampus: from space travel to time travel



The week ahead

- Today: The hippocampus, space travel to time travel
  - Passingham Chapter 4: Foundation for this and next class
  - In-class discussion
- Thursday: Episodic Memory; Rehearsing and retrieving memories
  - Reading: "How to see a Memory"
  - Lecture material is canvas videos
  - Last reading! Bird et. al., 2015

Learning Objectives: Motivated Attention (Classes 16-17)

- ✓Describe four evolutionarily conserved basic emotional/motivational systems
- ✓Explain ways in which amygdala and mid-brain dopamine systems play a role guiding *motivated attention*
- ✓Evaluate factors that influence individual differences in vulnerability to anxiety, addiction and depression

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Wrap-up: Attention Classes

- There are many kinds of attention and many brain systems that can guide it. We looked at a few.
- Sustained attention:
  - Multiple processes
  - Brain wide patterns of functional connectivity underlie individual differences

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Ok. We've spent the last chunk of classes looking at attention. What are some big picture take-homes?

Wrap-up: Attention

- Selective attention
  - Classic models: Top-down and Bottom-up
  - DAN and VAN *modulate* activity in sensory cortices
  - Motivated attention: Emotional relevance and expectation of reward (DA) also guide attention via amygdala and basal ganglia modulation of sensory cortices
    - Distinct patterns of *attentional bias* are linked to anxiety, depression, and addictive behaviours
- There is still a lot to learn about how all these systems compete with each other to see which one will win out to guide attention in different real-world situations

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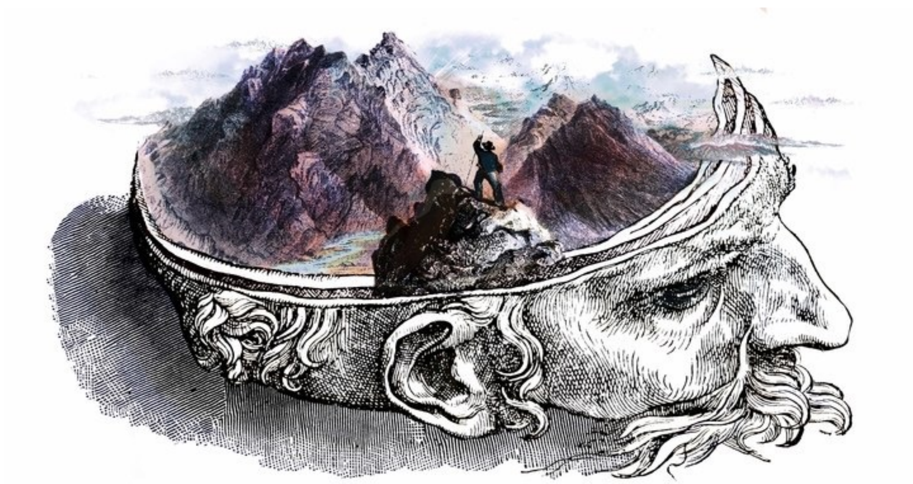
Next up we will move on to the hippocampus and memory systems.

Understanding episodic memory



Endel Tulving and Multiple Memory Systems

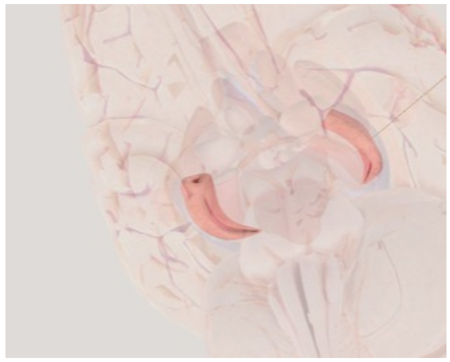
- Once upon a time psychologists believed there were two types of memory: Long-term and short-term memory
- It was Endel Tulving who suggested we have multiple memory systems in 1972.

Multiple memory systems

- Implicit (unconscious)
- Procedural Memory
- Performance of skilled action
- Conditioning
- Memory for emotional relevance revealed by actions

- Explicit (Conscious)
- Semantic Memory
  - *Facts*
- Episodic Memory
  - *Events* – mental time travel
- Autobiographical Memory
- Prospective Memory
  - Performance of future action

Focus on The Hippocampus



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What do we know about the hippocampus? We need it to form and recollect episodic memories, and to imagine future experiences. These are all forms of conscious memory where things happen in a sequence in time. The hippocampus is also crucial for our ability to navigateIt is thought to play a role in the generation of mental maps which may be what links the role of the hippocampus in time and space.

Navigation

https://www.youtube.com/watch?v=VOvy1woaJts&list=LL&index=8
Tom the Taxi Driver

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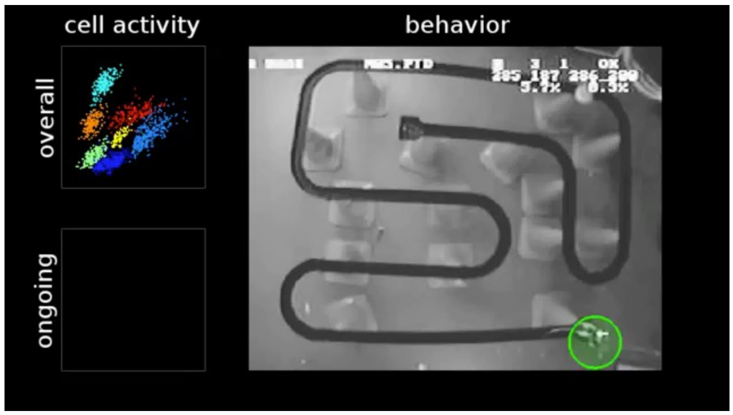
As you watch this video imagine yourself as the driver and notice all of the things you need to keep track of a s the driver.   Make a mental note of the things you're keeping track of. **Q: So what were you keeping track of?**

Rat navigation



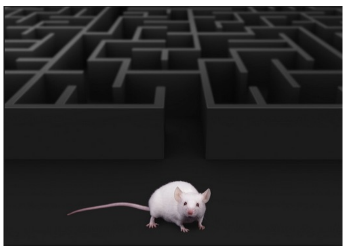
Place cells map. But not topographically or literally.

This shows the activity of 10 hippocampal "place cells" as a rat moves from one arm to another in a maze. Each cell's activity is shown with a different coloured dot on the track where each cell fires, as well as a "pop" sound. **Q:** What do you see happening here? How can you relate it to the driving video you just experienced?

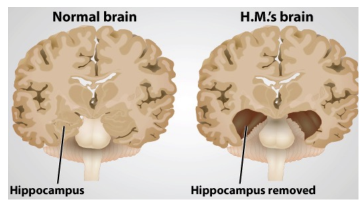
Place cells are thought to play a role in cognitive maps, which we'll talk about in a minute. There is no apparent topography to the pattern of place fields -- that means that the organization of where the cells that fire for different places doesn't map on to the relationship of the places they fire to in the world., neighboring place cells are as likely to have nearby "fields" or areas they respond to, as distant ones. Place cells also have the ability to suddenly change their firing pattern from one pattern to another, a phenomenon known as "re-mapping."

The historical conundrum

- Spatial Navigation



- Memory



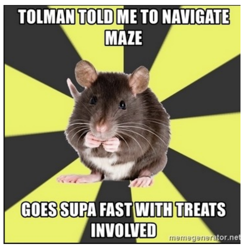
On the one hand we had lots of data for how the hippocampus works in spatial navigation in rats. For example in addition to place cells we now also know there are a number of other types of cells in hippocampus and other regions of the medial temporal lobe that play a role in navigation. Grid cells in the entorhinal cortex which is in the anterior tempooral lobe next to the hippocampus, and sends the hippocampus information. Rather than tagging specific locations, as place cells do, grid cells organize space into a gridlike map that is used in any environment. So where place cells will remap, these grids that organize space hold constant. And there are also head direction cells and border cells which track the edges of a spatial location.[1] On the other hand, we had human lesion data indicating the hippocampus was vital for episodic memory, or the ability to call up and relive or replay events. Recently researchers have begun to extend the idea of cognitive maps, first introduced in relation to rat spatial navigation, to episodic memory, or the ability to travel through time as well as space.

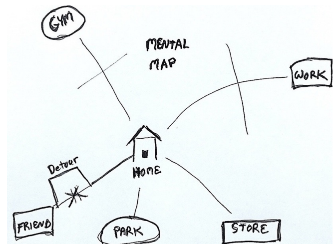
Learning Objectives: The hippocampus

- Explain the concept of a cognitive map
- Evaluate evidence for role of hippocampus in human navigation
- After the next series of lectures, link what we know about the role of the hippocampus in spatial navigation to its role in episodic memory

Cognitive Map Hypothesis

- The brain builds a representation, or mental map of the spatial environment to support memory and guide future action



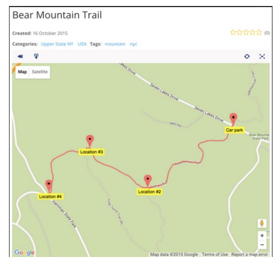


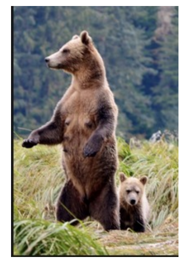
Cognitive maps are mental representations of physical locations. The term was introduced by psychologist Edward Tolman to explain how rats learned the locations of rewards in a maze. A cognitive map provided the rat with a useful model of the environment -- what locations were the place where relevant things are. Irrelevant or unimportant information is excluded from the mental map. Humans and animals use them to find their way and to help recall important features of the environment. Thus, cognitive maps can be very different from an actual place. Since Tolman introduced the idea it has been extended to include more metaphorical maps, such as schema. We will talk more about these later on, but briefly, Schemas are mental scripts of how certain situations tend to go, and these are seen as a way of organizing memories as they are laid down.

Functions of cognitive maps

- *Landmarks* link mental map to sensory information
  - Where are you in relation to something in the world you can perceive

- Planning a route to destination
  - Hippocampus





Let’s stick to the spatial version for now. Cognitive maps must be able to link the mental map to things really in the world that our senses can identify. That is where landmarks come in. These can be buildings or features of the landscape. I know where I am on my route to from the Kenny Building to Koerners by identifying the clock tower. Planning. When going from Kenny to Koerners I decide which path I will take along main Mall, passing the clock tower and turning left just before the rose garden at the flag circule. **A number of visual cortex regions play a role in identifying landmarks, including PPA which -- as Passingham describes -- is a region of the ventral visual cortex that is sensitive to scenes. It is in planning a route that the hippocampus plays an important role.** And planning a route requires you to actively remember features of the landscape as well as where you are in it and where you want to be.

Learning Objectives: The hippocampus

✓ Explain the concept of a cognitive map

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The role of the human: Hippocampus in City Navigation

Research questions:

1. When might the hippocampus be most required during an ongoing period of navigation?
2. Which specific navigation processes might it be most important for?

Reading taxi drivers' minds

- 20 London taxi drivers (mean age 49)
- fMRI scans
- Realistic VR of London
- Had to navigate to a destination in response to customer requests
- After scan watched video of route and reported what they were thinking

This is described in Passingham on p. 44. Talk about older structural findings wrt THE KNOWLEDGE. London taxi drivers not your fly by night uber drivers. And these drivers were from the days before taxis had GPS. They had to learn the Knowledge. 'The Knowledge'. This involves learning the layout of 25, 000 streets in the city, thousands of places of interest . Talk about hippocampal volume studies. Had previous training.

Active navigation via the getaway

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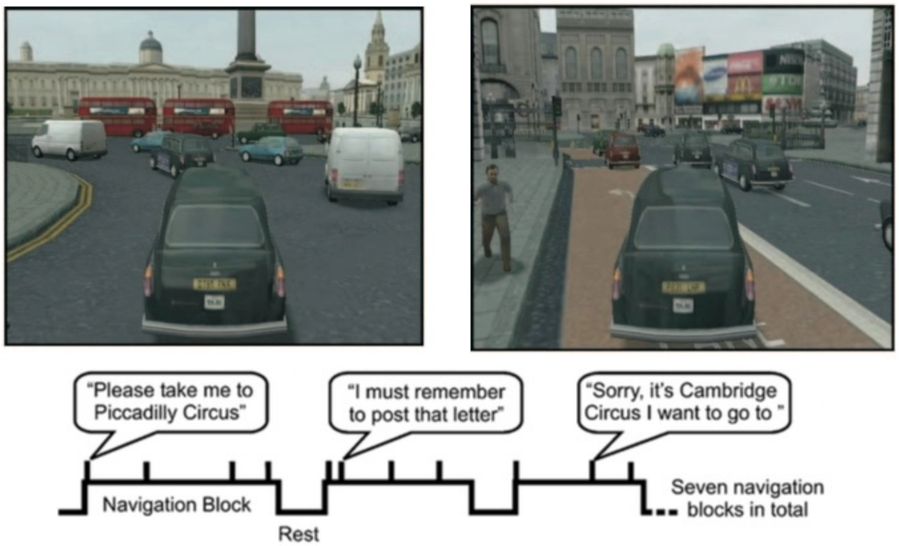
VR much more naturalistic and ecologically valid than simply having people look at one picture after another or even watching a movie– and what's key if you're interested in navigation is catching people in action not just passive viewing. Which is very hard if people have to lie perfectly still. This is where VR comes in!! Moreover, a lot of times experimental VR is kind of simplistic, whereas games are highly detailed. From video game "The Getaway". Conveniently, one can simply navigate freely around the city using the game console, with a normal ground-level first person perspective, in a car of one's choice. Subjects were taxi drivers: Taxi drivers have well developed cognitive maps – or used to!

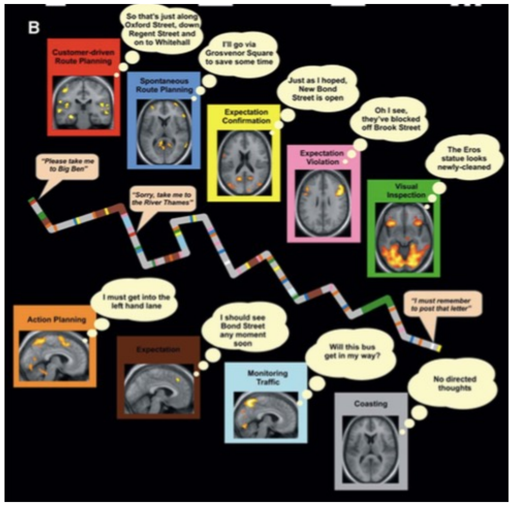
VR London

Spiers & Maguire, 2006



During fMRI scanning, navigation was tested in blocks where subjects responded to customers' requests (heard via headphones) by delivering them to their destinations. Customer requests would be first for one destination then part way they'd ask to change the destination. So they'd be headed to King's cross and the customer would say, "oh no go to Covent Garden." The driver would then need to re-plan the route from scratch. They would also hear some irrelevant statements from the customers. Then reported thoughts along the way. There were 7 different routes Again when the route changed they didn't have GPS – they had to consult their mental map and actively plan a new route.

Taxi thoughts



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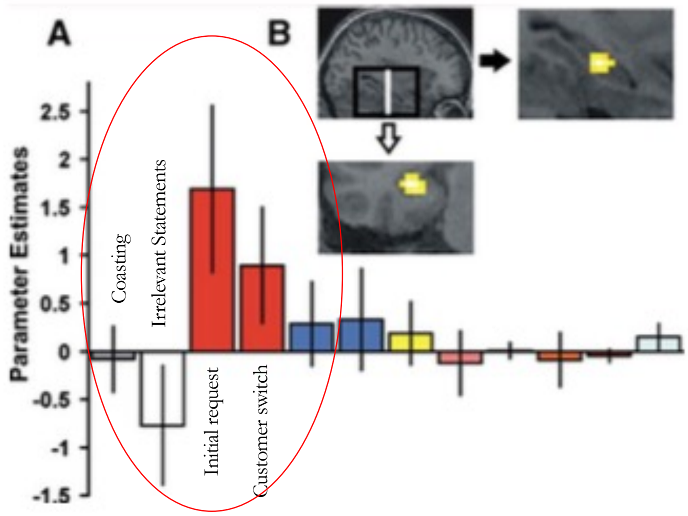
The third, and most crucial element of the study was the means by which we read the thoughts of subjects as they navigated. Immediately after the scan scan subjects watched the video replay of their performance and were interviewed. Go over each of these categories. Customer driven route planning – both initial destination and the switch. KEY TAKE HOME. Customer driven planning is where you see hippocampus activation.

Hippocampus activation

Spiers & Maguire, 2006



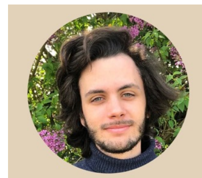
Summary

- Brief activation in hippocampus important for planning a route to a very specific destination
- NOT when alterations to the route are made on the fly or to update where they are in relation to goal
- Theory: Hippocampus retrieves relevant spatial information from a “cognitive map”
- But is this universally true in navigation?

Our finding is consistent with a view that during goal-specified route planning, the hippocampus activates, or retrieves from elsewhere, the information relating to the relevant region of space to be navigated from a stored cognitive map of the environment. **Q: Why might you not need the stored map when making decisions on the fly?** They say, based on previous research, ”generating the initial vector, updating the most efficient route, and observing landmarks to update the current vector to the goal, might all be likely candidates to show increased activity in the hippocampus. Whilst the first prediction is borne out by the current results, the latter two are not. Thus, our results provide an empirical basis from which models of hippocampal processing might be refined. “

Embodied, extended, relational cognitive maps

- Enactivism: Cognition emerges dynamically through bodies embedded in the environment
- Extended cognition: Cognition is distributed between humans, other humans, and the artifacts or tools we use
- Fernandez-Velasco & Spiers, 2024: Traditional navigational strategies are both local and inseparable from a larger cultural system



Pablo Fernandez-Velasco

- Interdisciplinary approach:
  - Phenomenology
  - Cognitive ethnography
  - Brain imaging
  - Gamified experiments
  - Survey instruments
  - Thematic analysis

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Hugo Spiers, who has studied taxi drivers for decades to understand human navigation, teamed up with philosopher Pablo Fernandez-Velasco to examine traditional navigation systems across cultures. Multidisciplinary

Wayfinding across ocean and tundra: what traditional cultures teach us about navigation

Pablo Fernandez-Velasco[1,2,*] and Hugo J. Spiers[1,*]

Research on human navigation by psychologists and neuroscientists has come mainly from a limited range of environments and participants inhabiting western countries. By contrast, numerous anthropological accounts illustrate the diverse ways in which cultures adapt to their surrounding environment to navigate. Here, we provide an overview of these studies and relate them to cognitive science research. The diversity of cues in traditional navigation is much higher and multimodal compared with navigation experiments in the laboratory. It typically involves an integrated system of methods, drawing on a detailed understanding of the environmental cues, specific tools, and forms part of a broader cultural system. We highlight recent methodological developments for measuring navigation skill and modelling behaviour that will aid future research into how culture and environment shape human navigation.

Our laboratory studies are strictly controlled, culturally specific, with WEIRD participants, and lack ecological validity. In contrast, this review paper provides an overview of anthropological studies of diverse forms of navigation systems.

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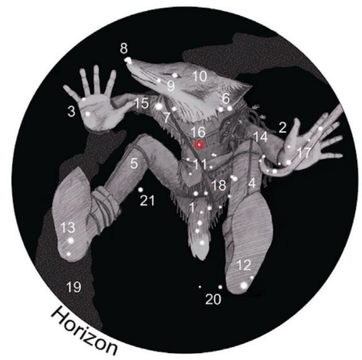
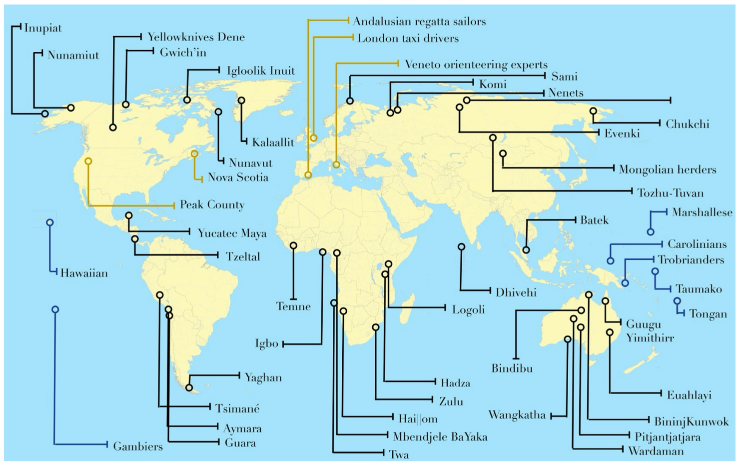


"Finding his way in the Yukon Flats of northern Alaska, the Gwich'in Elder Paul Herbert looks at the night sky and projects different stars onto attributes of the mythic fox-like creature Yahdii. The stars form the tail, leg, or snout of Yahdii, each pointing to different regions of the flatlands, guiding the traveller when no path or landmarks are available. There is a mapping between the constellation and local landmarks of the Gwich'in territory at given times, such that Yahdii can serve as a celestial schema for inland orientation. The projection of occluded parts of this anthropomorphic figure allows travellers to infer the locations and spatial relationships of all its stars even when the constellation is partially obscured. "

World Map of Traditional Navigation Cultures



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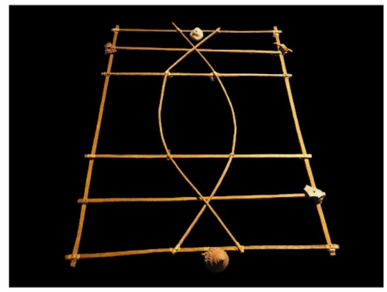
"The Gwich'in celestial scheme is paradigmatic of most traditional navigation in that it is both local and inseparable from a larger cultural system: to use it one must learn particular constellations, placenames, and mythology. Using such systems, humans show remarkable feats of navigation across a variety of environments, from trekking dense tundra, to sailing vast oceans, to negotiating the streets of sprawling cities. Humans exploit a rich diversity of strategies to achieve this. While experimental research in the laboratory has helped uncover the cognitive features and brain systems underlying navigation, most studies test western participants in highly controlled settings and, thus, ignore the heterogeneity of cultures and environments that humans navigate."

One assumption in most cognitive science studies of navigation is that expert navigation corre-sponds to the use of allocentric representations where - locations of objects are not coded in relation to the observer but in relation to other objects and to global landmarks. When I look at a street map and interpret north and south without any "you are here." However, this is not necessarily the case. They can be, to different degrees, allocentric– or egocentric – that is, coded in relationship to the first-person observer - to my right or left, above me or below me. And where we have mostly studied the role of vision in navigation, they also draw on a wide range of sensory systems – auditory, proprioceptive (feeling of your body/body parts in space), haptic (touch), smell.

(B)



.raditional sea navigation in the Marshall Islands relies on wave piloting. Navigators guide their canoes by reference to changes in swell and current patterns, which they use to determine the location of faraway islands. During training, this embodied knowledge is combined with learning from ‘stick charts’, made from coconut strips and cowrie shells, which model wave concepts and interrelate locations of known wave patterns, with shells indicating the location of reefs or islands. At sea, navigators decide on an initial course based on their knowledge of the configuration of islands, and then use changes in the rhythmic motion of the canoe to sense the transformation of wave patterns . For the Marshallese, the understanding of wave patterns is a form of practical knowledge. While there is a linguistic element to the learning and naming of wave patterns, describing the pro-cess is a challenge because feeling the waves is primarily action oriented.

(C)

Knowledge School material in use by apprentice taxi drivers who used to have to memorize all the streets of London. Maps are used to learn relations between places, to help with directional studies, and for planning the fastest routes

Technique	Example populations
Environmental Cues	
Stars	Gwich'in
Waves, Ocean Swell	Marshall Islanders
Landmarks, Street names	Londoners
Systematized Knowledge	
Inland stellar wayfinding	Gwich'in
Landscape directionals	Inuit
The Knowledge	London taxi drivers
Visualization Techniques	
Projecting Constellations	Gwich'in
Imaginary Landmarks	Micronesian navigation
Birds eye view, in-street view	London taxi drivers
Cognitive Artifacts	
Stick charts	Marshall Islands
Tactile maps	Inuit
London A-Z (street maps)	Londoners

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Importantly, the authors claim that each of these navigation systems is not just procedural (how to) but conceptual and theoretical. Here is how they categorize the different components of these systems. Directionals: Different Inuit groups are famous for using the direction of the wind to maintain a given orientation, and cloud formations, sea waves, and animal behaviour can all be used to infer incoming shifts in the wind' Tactile maps are made of carved driftwood representing coastline

Main Takeaways

- Traditional cognitive science has overlooked:
  - Non-visual senses
  - Visualization techniques
  - The role of language and naming
  - The role of navigation tools/artifacts
  - The role of culture and local knowledge
- Broader view of navigation *"moves away from a narrow focus on internalized memory representations of spatial locations toward an understanding of navigation as a dynamic, action-oriented skill involving a heterogenous set of cognitive resources and heuristic."*

Fernandez-Velasco & Spiers, 2024

Brain systems used in navigation -- AND memory – change with age and a broader perspective may be required to understand these kind of changes as well.

Question

- What role might the hippocampus play in each of these diverse modes of navigation?
  - Is there a common process that engages the hippocampus or do each of these engage distinct constellations of brain systems?

How might you study that?

The Hippocampus In Navigation

- Hippocampus important in laying down cognitive maps, or a more abstract representation of a physical or metaphorical landscape
- Hippocampus is active in calling up detailed representations of spatial information
- It is involved particularly in beginning stages of goal-directed navigation – planning routes to specific goals
- What is its role in other systems of wayfinding?

Learning Objectives: The hippocampus

- ✓Explain the concept of a cognitive map
- ✓Evaluate evidence for role of hippocampus in human navigation
- After the next series of lectures, link what we know about the role of the hippocampus in spatial navigation to its role in episodic memory

Next up: Episodic memory and what it’s like to lose it