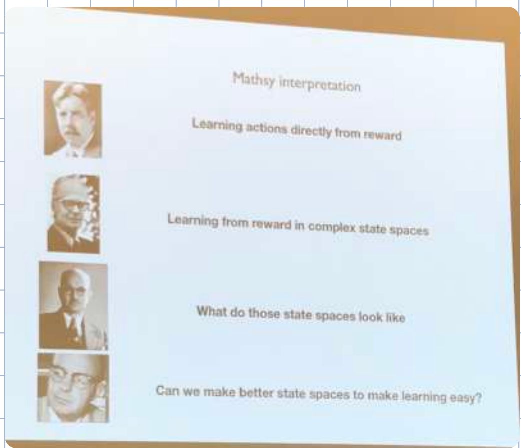
Tutorial - Day 0 - T. Behrens & K. Stachenfeld 13/08/19

— 'Representing States and Spaces' —

- (1) Thorndike → Law of effect ⇒ (2) Pavlov / Skinner ⇒ Reward-based learning
  ↳ SHAPING
- (3) Tolman → cognitive map ⇒ Value-based MF vs. Model-Based
- (4) Harlow et al 1949 ⇒ Mixture MB ⟺ MF → learning sets!



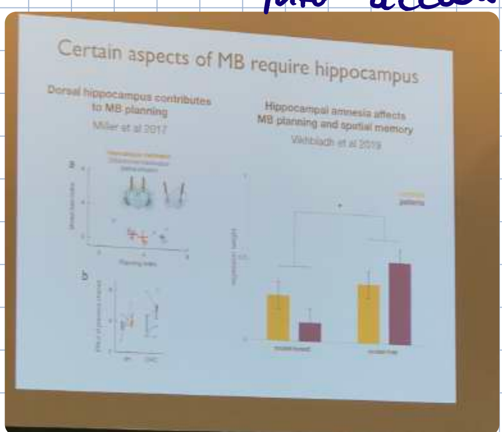
(1)
(2)
(3)
(4)

RL Problem!

SECTION ON RL PROBLEM (1) + (2)

- Exploration trick: Optimistic Init
  ↳ set values high ⇒ always explore all actions in all states once!
- MF value propagation ⇒ sample inefficiency
  ↳ Improve by using the "right" state space representation!

- Schultz et al. → Reward Prediction Error Hypothesis ⟷ Dopamine Firing Rate
- Model-based RL: Tolman! → Simulated Model of World
  → Johnson & Redish (2005) ⇒ Hippocampal activity → Predictive sweeps
  ↳ Especially at decision points! ⇒ sharp-wave ripple
- PFC ⇒ Model-Based vs. Striatum ⇒ Model-Free
- Disect both forms of learning experimentally → Daw et al. 11' 2-step task
  ↳ Do you take transition structure into account ⇒ reaction after farted transition



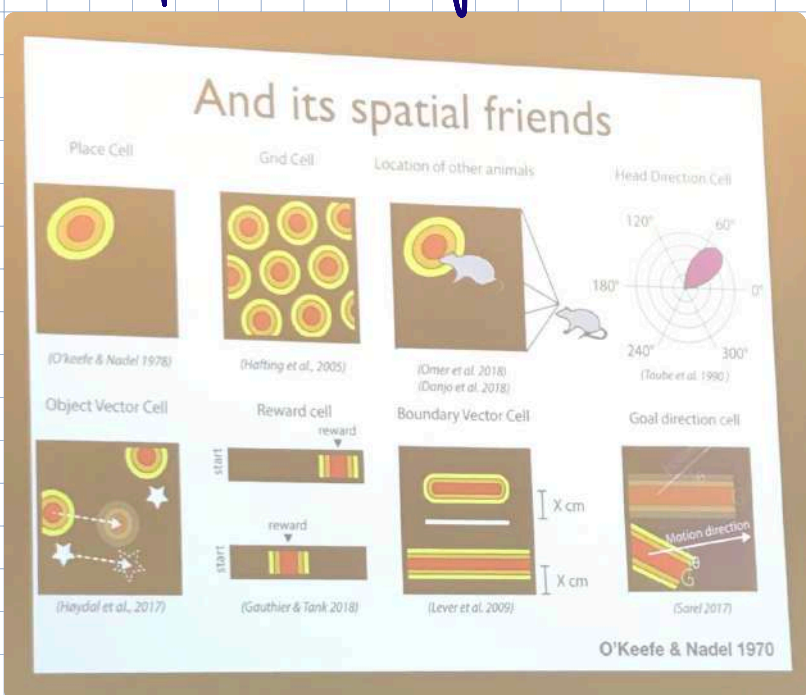
- How to integrate both systems!
  (1) Arbitration: MF / MB both propose
  (2) MB trains MF: Dyna - Sutton 91'
  (3) MC Tree-Search ⇒ Hiramatsu et al 16'

- Mattar & Daw 18' ⇒ Optimal backups for Dyna → Gain Terms!
  ↳ Select transitions based on effect on policy update! ⊕
  ↳ Explains variability in hippocampus ripples! — how important are states!

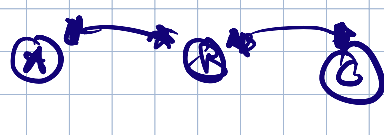
- THETA SWEEPS → happen when animal behaving!
  SHARP WAVE RIPPLES (SWR) → rest / sleep!
  ↳ Hypothesis: During sleep model-based system trains MF system

SECTION ON STATE SPACES 3 + 4

- Geometry exploitation vs. Past experience replication
  ↳ Statistics of roadmaps! ⇒ Disentangle path → shortest vector
  → Hippocampus as cognitive map ⇒ O'Keefe & Nadel 1970
  ↳ place cells, grid cells, other animals, etc.



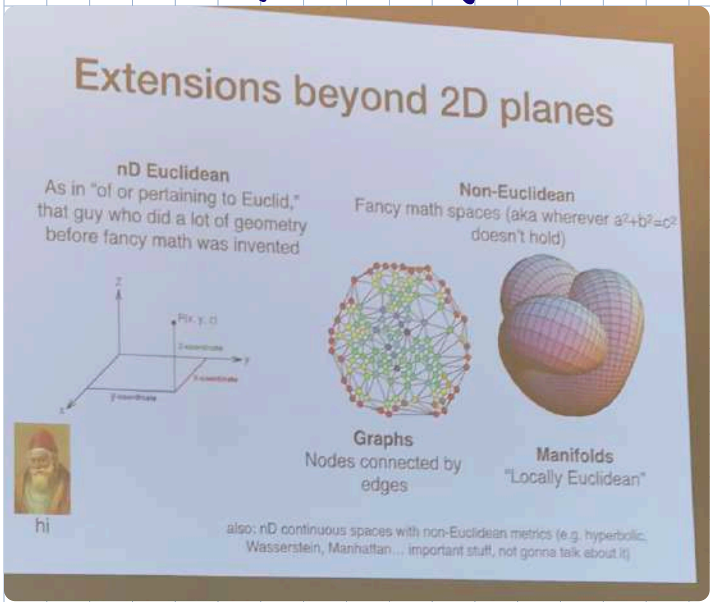
- Remapping ⇒ different degrees → Global vs. Rate
  ↳ Transfer of topological maps across cells ⇒ HARD without traces of correlations
  ↳ Redundancy in recordings!
  ↳ Context vs. Structure of env!



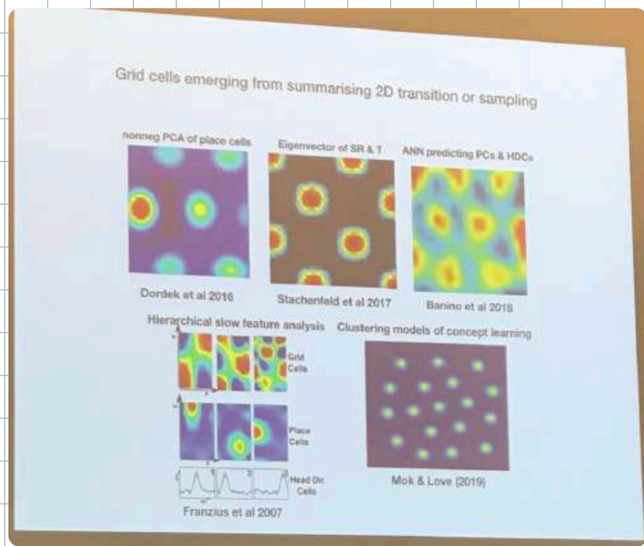
1st line!

- Dusek et al 97' ⇒ Relational inference in hippocampus ⇒ Transitive
- Hexagonal free emergence across different types of tasks!
  ↳ in PFC: Jacobs et al 13' ⇒ Grid cells! → Maps outside hippocampus

- Hexagonal coding ⇒ 3D → 2D compressed! ⇒ Klukas et al 19'



- Graph ⇒ State as Node!
  ⇒ Transition as Weight/Edge



Modelling work on emergence of grid cells ⇒
↳ transition matrix ⇒ top eigenvectors
↳ Find grid cells in there! ⇒ grid code similarity = repr. similarity

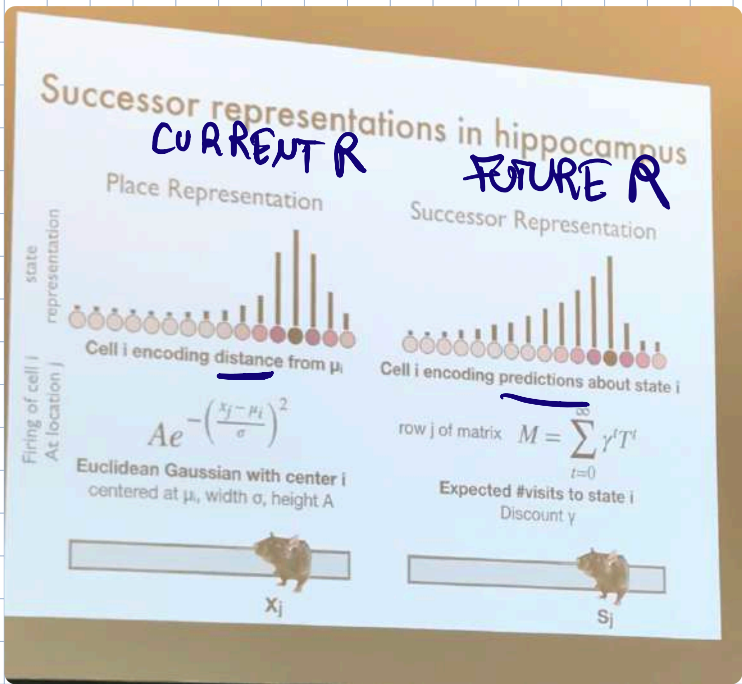
- Markov assumption → Conditional independence ⇒ Context vs Memory
  ↳ cognitive load reduced!
- Male stickleback fish → Male = red under belly ⇒ strong behavior
- Learning of abstract representation space ⟺ Exploration/active inference
  → Latent states ⇒ OFC! → Wilson & Niv, Schuck & Niv 16', 19'
- Hippocampal splitting → Wood et al 2000 → context (action dependent activity!
- Structured evaluation of states ⇒ Hippocampus → Entorhinals from ball cells!
  ↳ SENSORY INTEGRATION W. TIMESTAMP

What is a good representation?

- Predictive ⇒ Successor Representation
- Disentangled ⇒ Separate routing
- Low-Dim ⇒ Easiest to learn, less
- Hierarchical ⇒ level of abstraction
- Transfer ⇒ across Tasks
- Relational ⇒ Task connectivity

PREDICTIVE

- Successor Representations in Hippocampus → Stachenfeld et al 17'



↳ Transfer! ⇒ Transfer of value locations!

↳ Successor vs. Eligibility

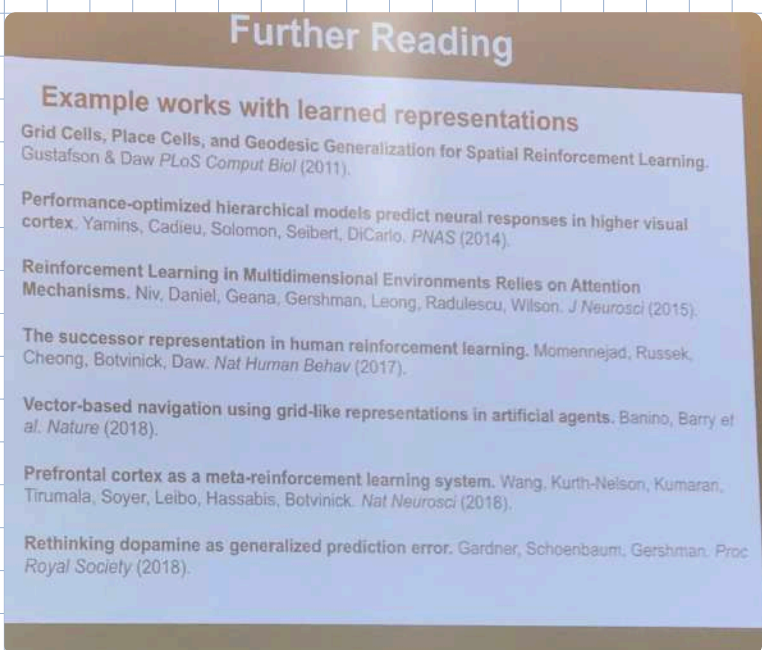
LOW-DIM

- Combat CoD!
- Eigenvector ⟺ Compression
  ↳ largest EV captures most variance in specific matrix
  ⇒ moment!

- PCA, etc. (dim. reduction) ⇒ Compressed Representations

// Bayesian Section ⇒ Learn + invert generative model

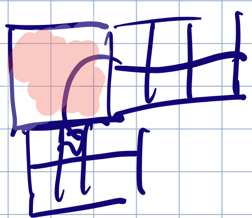
- Helmholtz Machine → Hinton, Dayan (1995) → competition
- VAEs → Kingma & Welling 13' ⇒ learn latent transition structures
  ↳ HOLISTIC RL → add memory element // hippocampus → Behrens Recent work!



See keynote tomorrow!

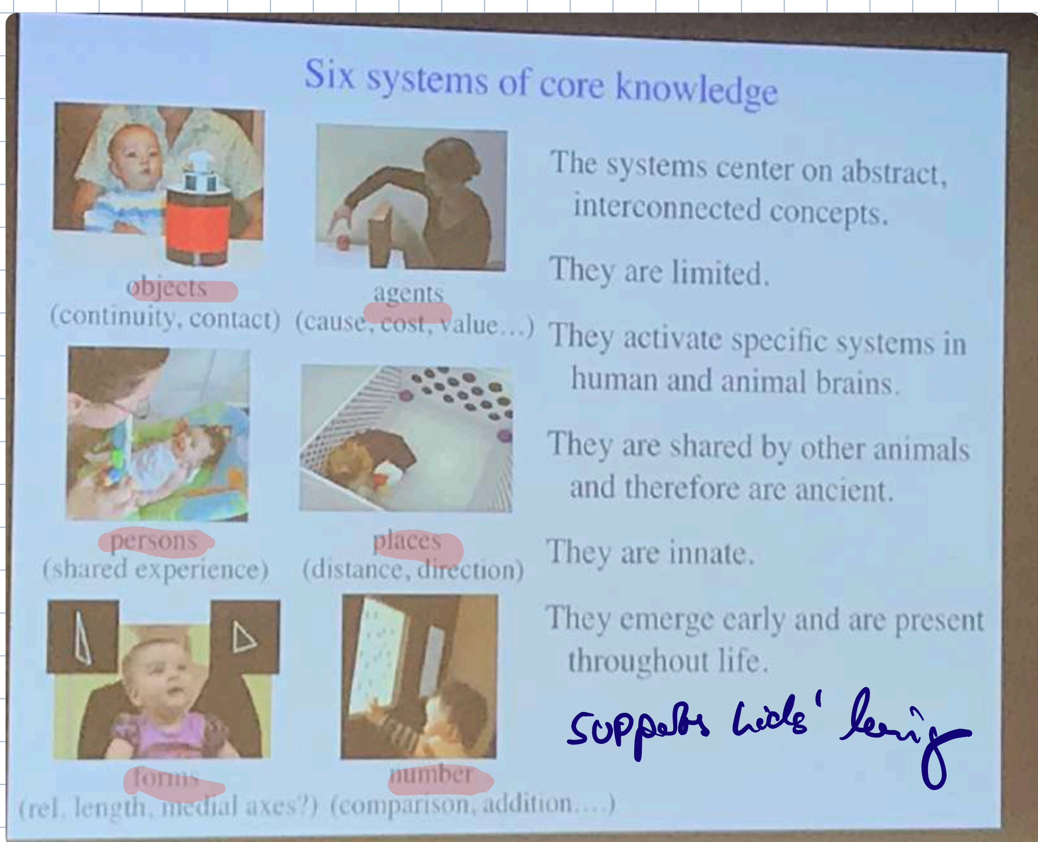
Liz Spelke – 'From core systems to new concepts of knowledge'

- Infant/kid learning ⇒ Highest general intelligence → 0–5 year old kids
  ↳ high variability across nature of tasks that kids have to master!
  ↳ across cultures and subjective endowment!
- Fast & Flexible learning → Here: Developmental Psychology PoV
- Eleanor Gibson – Visual Cliff ⇒ Developmental psychophysics



→ Avoid depth (secure w. plexiglass)
↳ Goats: From birth   ↳ Rats: First vis. exp.
↳ Infants: From crawling
↳ Cats: Perceptual learning over time!   ← of objects!
⇒ depth perception is innate, not shaped by experience learning
⇒ Ancient Mechanism / Visual Exploration / Time

INFANT CORE KNOWLEDGE SYSTEMS



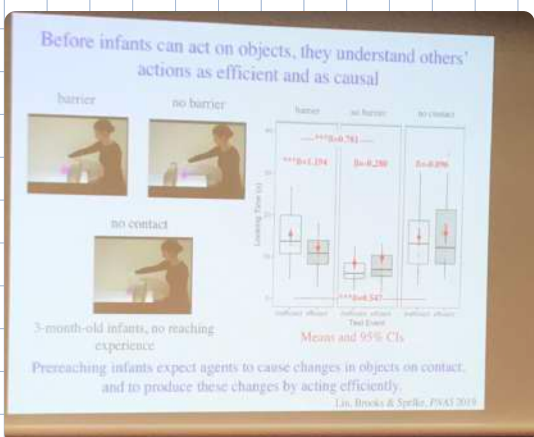
supports kids' learning

all are related
↓
ANCIENT
↓
Meta-Learning

- Places ⇒ abstract concepts → limited ⇒ support of learning
  - ↳ distance + relative directions relevant // not color/texture!
  - ↳ Navigation follows after perception ⇒ Not directly
    - ↳ But how is this learned?! ⇒ End-to-end?!
  - ↳ series of experiments by Lee & Spelke
  - ↳ How is action planning learned? → Hard to study since process seems to be very slow!
  - ↳ place cells → grid cells → border cells [DEVELOP]
    - ↳ LEARNING / EXPLORATION REQUIRED!
  - ↳ learning support ⇒ Re-orientation → self-supervised!
    - ⇒ Not evolutionary but afterwards!

⇒ EUCLIDEAN NATURE OF WORLD → CONSTANT ACROSS EVOL.

- Universally useful abstractions will emerge early on → help most!
  - → open-ended systems of concepts ⇒ generated by productive rules
- Important point in time when kids realize that numbers are exact representations ⇒ Important symbolic manipulation realization
- Tool use — End of 1st year
  - → but no direct functionality assoc.
  - → detection vs. usage of object features → not insensitive!
  - → 7 months: Assoc. movement with specific objects



- → Liu, Brooks, Spelke PNAS 19' ⇒ Causal + Efficiency
  - ↳ Required to learn! ⇒ OBSERVER
- Language ⇒ Person / Object / Form / Function
  - ↳ COMPOSITION OF CORE SYSTEMS

Grammars → More general integration ⇒ Following logic/ Symbolic Rules of Nature!