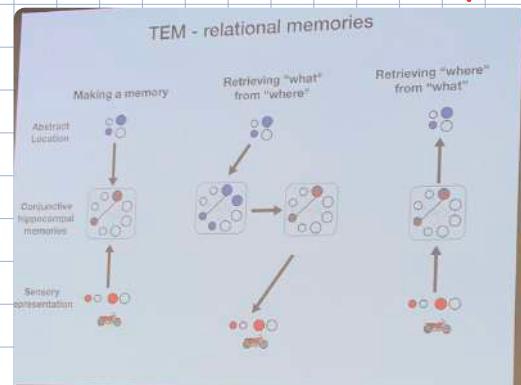
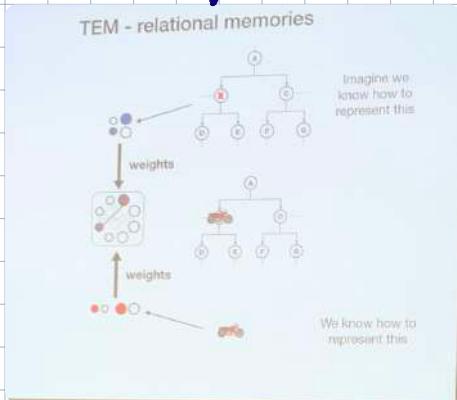


-'Abstraction and inference in relational circuits' -

- Structural knowledge allows for inference → COGNITIVE MAP 
- facilitated by different cells in hippocampal formation
- Special case ⇒ relational → 'reformulation' on like  $a > b > c > d$   
↳ Memory study ⇒ PFC required!
- Grid cells might be involved in non-spatial tasks! → solitary
- False integration in non-spatial graphs → Tolman Eichenbaum Hocken (TEM)
  - completion of graphs from limited info about relations!
  - Task transfer to new relational map! ⇒ one-shot
- Requires 2 things:
  - ① Abstract relationship representations ⇒ Refinement based on backup
  - ② Memory ⇒ Hippocampus (only complete) ⇒ but require retrieval anyway

Manns &  
Eichenbaum '06'



⇒ Overall principle of Boltzmann's machine!

- two representational requirements:
  1. Each edge in graph has to uniquely represented
  2. Unique indexing
- Inference on graph ⇒ Completion of relationships → generalizable

↳ Reference based on correct completion on the graph!

↳ Fct. of nodes seen on graph  $\Rightarrow$  not transities

- Resulting representations  $\rightarrow$  Grid like structure
  - $\rightarrow$  hypothesis: Optimal encoding of 2D relational space
  - $\rightarrow$  Extension: 'Zoo of cells'  $\Rightarrow$  BASIS SET OF TRANSITIONS
  - $\rightarrow$  result in RL context: Formalisation of concept of walls  $\Rightarrow$  RAPID INFERENCE + TRANSFER!

- Generalisation across Environments  $\xrightarrow{\quad}$  BUT HOW TRANSFER?
- Hippocampus: Global remapping  $\Rightarrow$  place cells orthogonal
  - $\rightarrow$  Try to predict remapping since place stays the same!  
↳ leads to similar correlation structure as data!
- Human dentate  $\Rightarrow$  closer objects in graph  $\Leftrightarrow$  smaller represent. distance!
- Hebbian in Human Replay
  - $\rightarrow$  Generative model required for training TEM
  - $\rightarrow$  Sharp Wave Ripples (SWR)  $\Leftrightarrow$  Replay as a generative model ?  
↳ Hinton & Dayan  $\Rightarrow$  Contradictive divergence  $\rightarrow$  RBL theory
- MEG  $\rightarrow$  Replay after presentation of images!
  - $\hookrightarrow$  Liu et al 18' (Cell), Kralj-Velickovic et al 16' (Neuro)
  - $\rightarrow$  forward / backward  $\Rightarrow$  Really fast 10-50ms
  - $\rightarrow$  Experiment: Remapping / Wiggle  $\rightarrow$  Replay allowed to infer the rules of the re-ordering

Ok back to abstraction

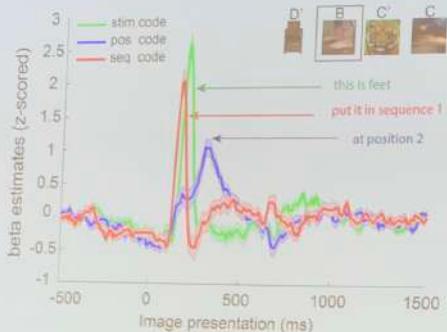
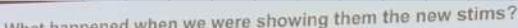
Did our replay look like this:



Or might it have looked like this:



Can it infer new sequences even if  
it has never seen the transitions



To evidence for alterations in forest!

## Conclusions

- Relational reasoning and space are the same thing.
  - Relational structure is abstracted and represented explicitly.
  - Entorhinal cells are a basis for transition structure.
  - Hippocampal remapping isn't random.
    - Relational structure is preserved
  - Replay can spontaneously reorganise experience
  - It might use these abstract representations to do so.

## • Q: Poetry

Tischigawer?

# Roshan Cools - Chemistry of Adaptive Mind - Dopamine $\rightarrow$ Metal Work

- Flexible adaptation within constraints  $\Rightarrow$  dopamine / noradrenergic
- $\rightarrow$  Herz: focus on stability vs. flexibility  $\rightarrow$  FOCUS is costly!

## • Principles of Neuroadaptation

- $\rightarrow$  Regional specialization
- $\rightarrow$  self-reinforcement
- $\rightarrow$  Baseline dependency

- ①  $\rightarrow$  In/Output dependent plasticity
- ②  $\rightarrow$  Equilibrium Maintenance
- ③  $\rightarrow$  fading effect if level already high

## • Prefrontal

B

CONTROL / MEMORY

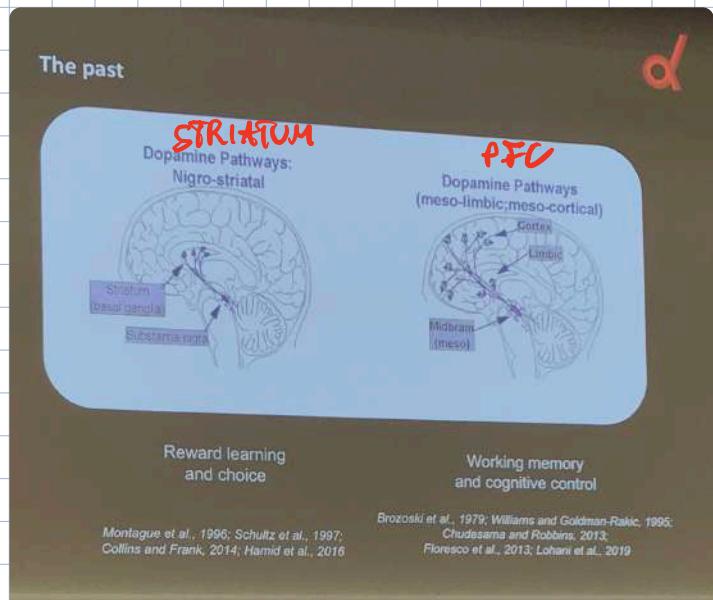
## rs. Striatum

B

REWARD / CHOICE

Dopamine  $\rightarrow$  Dual View

- Problem  $\Rightarrow$  large variability of drug effects by being dopamine
- $\rightarrow$  Concentration vs. Gambling!  $\rightarrow$  BASELINE STATE



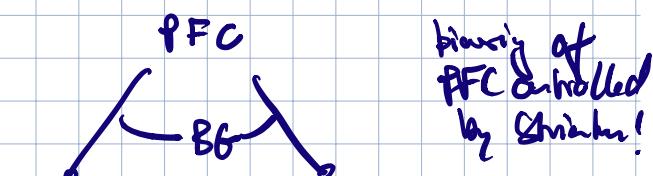
$\downarrow$  MODULATION  $\downarrow$

FLEXIBILITY  $\leftrightarrow$  STABILITY

Tach-Switch

Distracter

- How? does regulation happen!
- $\rightarrow$  COGNITIVE GATING!



FFA  $\rightarrow$  Object vision

$\hookrightarrow$  Dynamic Causal Modeling

$\hookrightarrow$  functional connectivity is key

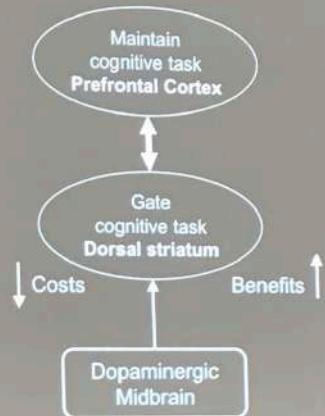
$\hookrightarrow$  Specific drug targeting

Michael Frank  $\rightarrow$  look up!

- Striatal dopamine  $\Rightarrow$  modulation of value of cognitive work!  
 ↳ Drug modulation study!  $\Rightarrow$  sensitivity to drugs in benefits (sleeping) and costs (feeling)

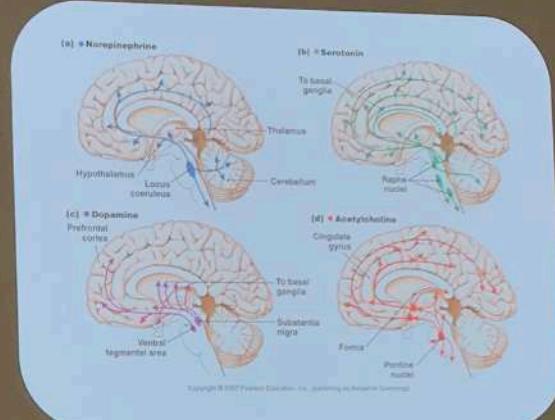
### Interim Conclusion

Striatal dopamine gates a cognitive task in proportion to its benefits versus costs



### Take home message

Chemical neuromodulators adapt structurally fixed neural systems to our changing environment



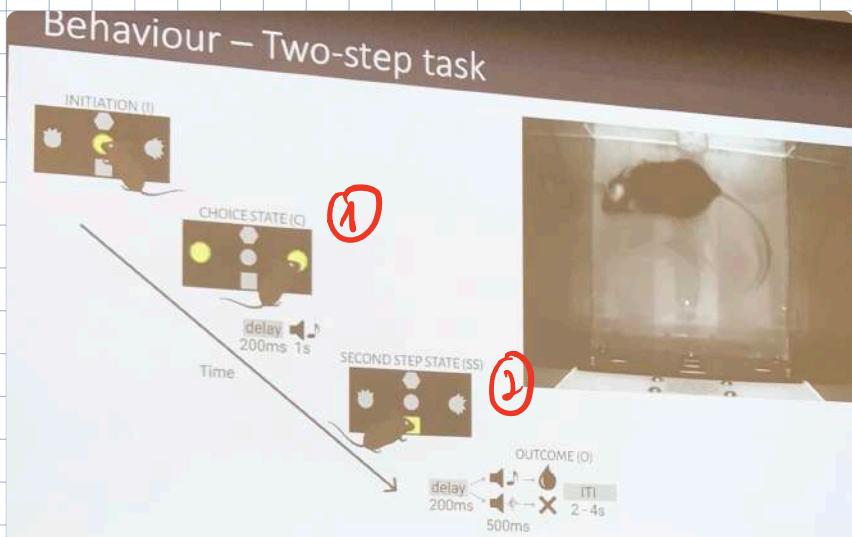
$\Rightarrow$  BUT WHAT CONTROLS THE MIDBRAIN?

↳ HYPOTHESIS  $\rightarrow$  MEDIAL FRONTOLENTICULAR CORTEX

- Emission to offer trade-offs!  $\rightarrow$  Dorsal vs. Ventral Striatum!  
 ↳ Meta-level optimization  $\Rightarrow$  Relationship to MFC-RL theory  
 ↳ Task-rele ifore
- Not clear which timescales are affected in which way by drugs!
- Influence of environmental statistics on baseline levels
- Pleasure from mental work  $\Rightarrow$  Goldilocks's level  
 ↳ Not if we can already predict to fail!

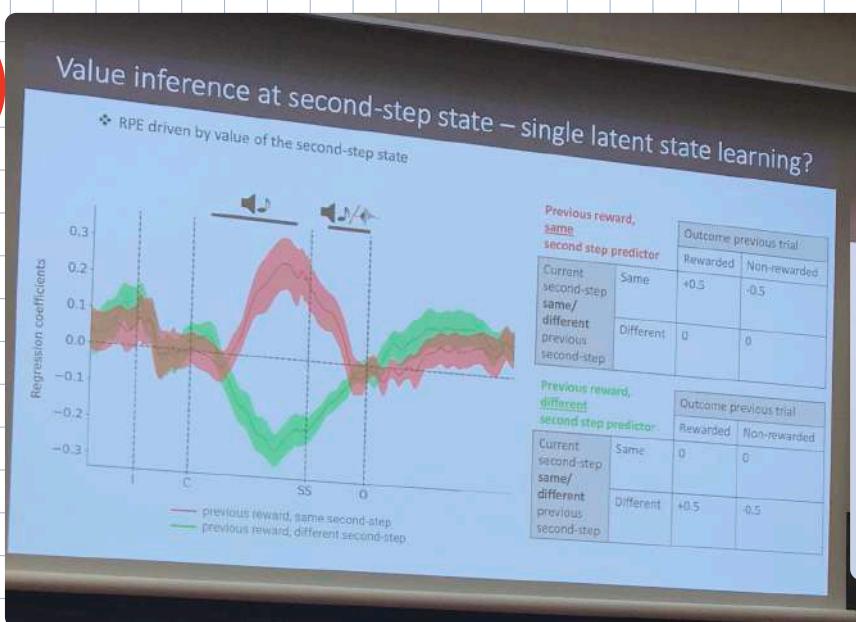
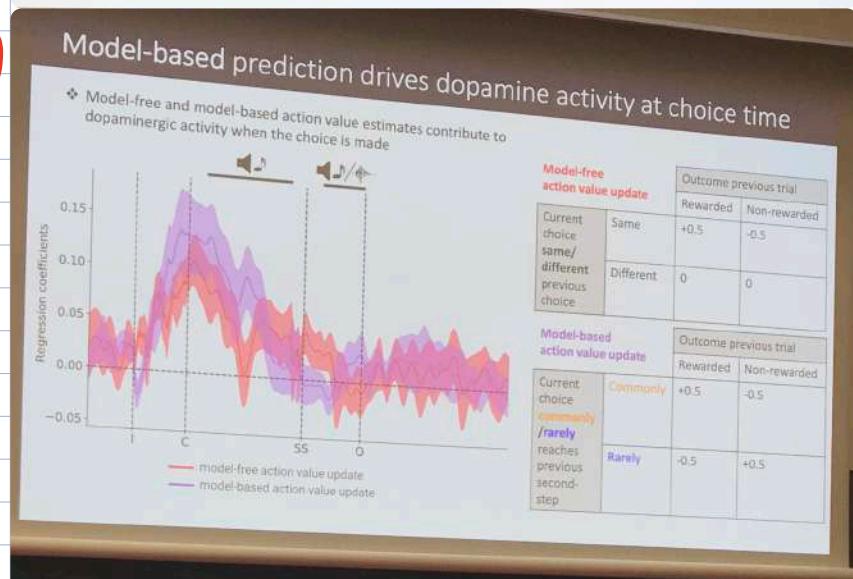
# Contributed Talk - Marta Pozo - (Model-Based value in Midbrain Dopamine Neurons)

- Dopamine  $\leftrightarrow$  MB - Competition  $\rightarrow$  2-Step Task  $\Rightarrow$  Duh et al 11'  $\rightarrow$  Choice behavior depends on incentives!



## Fibre Photometry

- MF vs. MB update effect on next choice!  
 $\hookrightarrow$  Predictive



## CONCLUSIONS

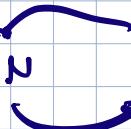
- Choice behaviour is consistent with model-based reinforcement learning
- Mixture of reward signals at different timescales
- VTA & NAc encode value information respecting task structure, the anti-correlated nature of reward probabilities, and transition structure linking actions and states
  - Consistent with Bromberg-Martin et al., 2010; Sadacca, Jones, & Schoenbaum, 2016; Starkweather et al., 2017; Takahashi et al., 2017; Engelhard et al., 2019
- Dopamine in DMS is primarily influenced by direction of animal's initial chosen action
- Dopamine contains multiple representations beyond model-free RPEs

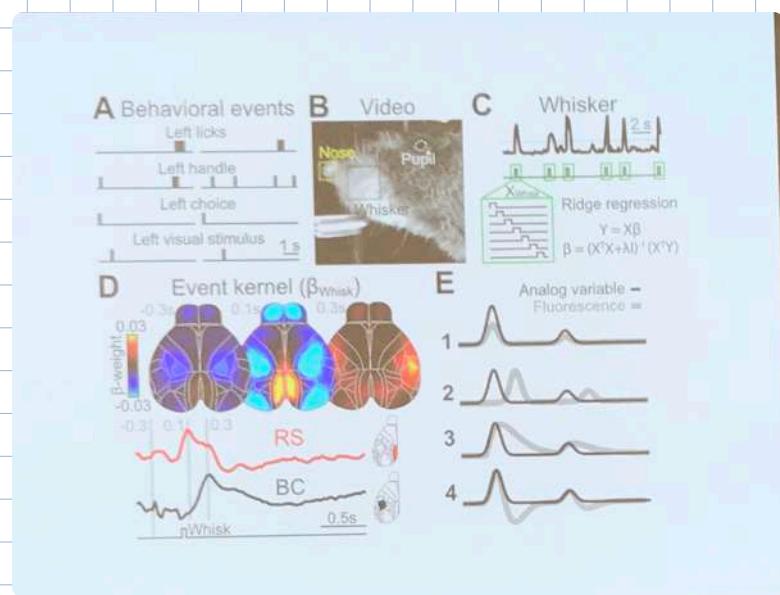
Stone Churchill - Single-trial neural dynamics during choice & expert decisions are dominated by rapidly varied moment

- Main challenge: Underlying neural activity  $\Rightarrow$  Moment vs. Categorical.  
 $\rightarrow$  Importance of unstructured moments  $\Rightarrow$  Task-aligned vs. Independent!
- Auditory / Visual spatial detection task  $\rightarrow$  head-fixed!  
 $\rightarrow$  Interested in prioritization objectives in recording  
 $\rightarrow$  Behavior quantification from video frames  
 $\rightarrow$  2-photon imaging w. intact skull  $\rightarrow$  full dorsal cortex
- Problem Recordings  $\rightarrow$  Every leg lights up  $\Rightarrow$  stim.-red. 2000 sf  
 $\rightarrow$  Build encoding model together with behavioral data from video  
 $\rightarrow$  Ridge regressors  $\Rightarrow$  Temporal event kernels  
 $\rightarrow$  Filters over lag regressors
  - $\hookrightarrow$  Good fit  $\Rightarrow$  Problem: Unstructured moment dominates activity
  - $\hookrightarrow$  Feed full frame as input  $\Rightarrow$  Explained most of var  
 $\Rightarrow$  Unclear what actually mattered!
  - $\hookrightarrow$  Headcup  $\Rightarrow$  weight requirement  $\rightarrow$  INTERPRET!
  - $\hookrightarrow$  Barhy...., Pandushi et al 19'  $\rightarrow$  NEURIPS  $\rightarrow$  Video!
- Implications: Single trial vs. trial averaged  
 $\rightarrow$  Over time / training days importance of unstructured moments ( $\downarrow$ )  
explainable parts
  - $\hookrightarrow$  Still stable  $\Rightarrow$  LEARNED HABITS
  - $\hookrightarrow$  Lots of legancy in the task!  $\Rightarrow$  PURPOSE?
- Counting well on decision making w. exc./inh. neurons separately correctly

# SOFT SKILL NOTES

- Churchill: 'Sceptic's corner'  $\Rightarrow$  addresses issues
- Cooks: Speak slowly and clearly!  $\rightarrow$  Not too much info!

- Does this generalize to humans  $\rightarrow$  COGNITION  MOVEMENTS  
 $\Rightarrow$  SEQUENCE INTRODUCTION



- Meta-bolic costs too high for random movements not being relevant!