Computational mechanisms of temporal duration sequence learning and memory in humans and rodents

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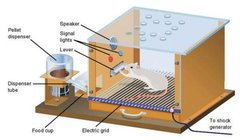
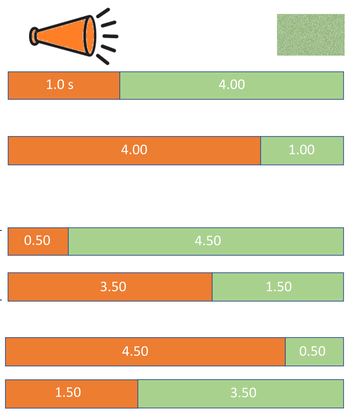
Introduction

- Our knowledge of human temporal memory has been informed significantly by rodent work (e.g., hippocampal "time cells"[1-2]).
- Limited research, however, has directly compared the two species with respect to behaviour.
- We developed a cross species temporal sequence learning task based on a paradigm that recruits the human hippocampus[3].
- We propose a novel computational learning model that captures learning dynamics and interindividual variability in humans and rodents during the acquisition of temporal sequence memory.

Method and Modelling

Sequence Learning Paradigm



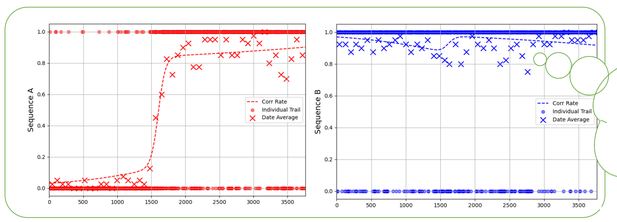


Participants

16 Long Evans rats (male = 8, female = 8), age = 10 weeks+.

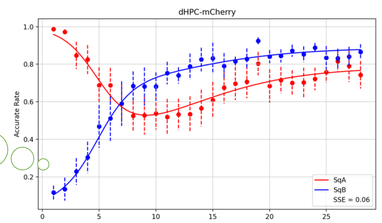
38 Human participants (male = 16, female = 22), age = 18 – 45.

Why do we need a new learning model?



Sigmoid model that accounts for only 1 sequence CANNOT capture **learning strategy**.

We need another model to represent **preference/memory**.



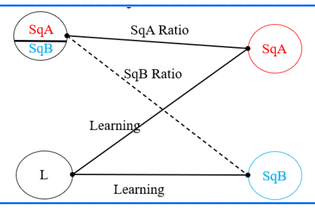
Sequence Learning and Preference/Memory Model

Model Sketch:

SqA = P(L) + [1 - P(L)] * SqA pref/mem ratio

SqB = P(L) + [1 - P(L)] * SqB pref/mem ratio

Learning Component: same for SqA & SqB

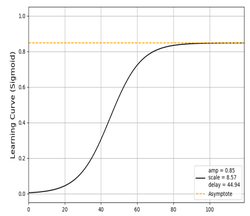


Learning Component

Parameter:

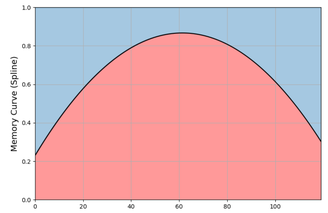
- amplitude (learning outcome)
- scale (leaning speed)
- delay (learning latency)

$$L = amp\_L * \frac{1}{1 + e^{\frac{(x - delay\_L)}{scale\_l}}}$$

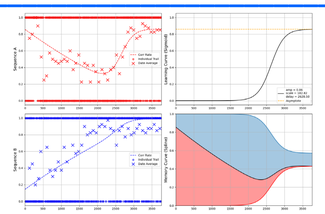
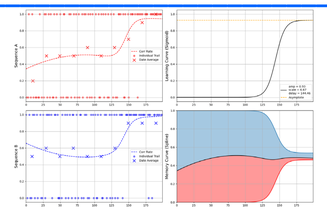
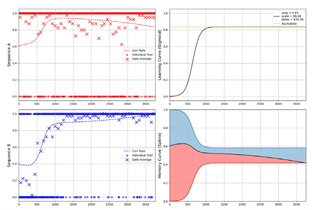
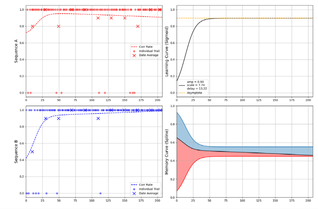
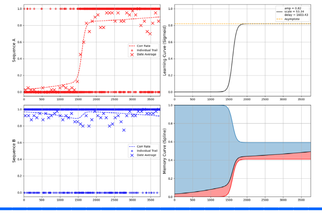
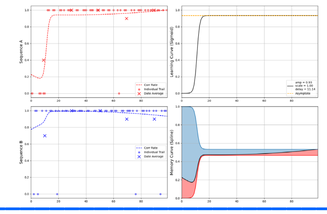
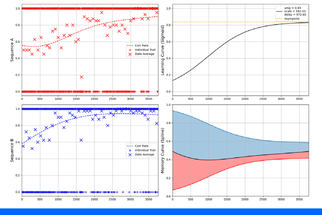
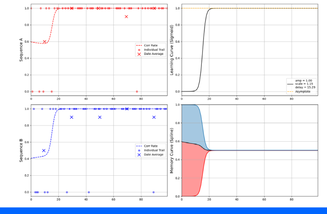


Pref/mem Component (cubic spline):

SqA pref/mem ratio + SqB pref/mem ratio= 1



Different learning dynamics in rodents and humans

	Rodents	Humans
Slow Learners		
Quick Learners		
SqB strategy		
SqA+B strategy		

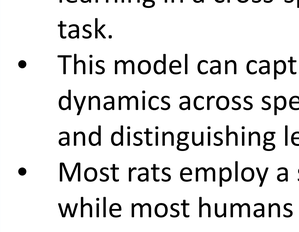
Results Summary

Percent Learned

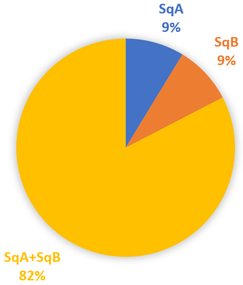
Rats (94%); Humans (61%)

Learning Strategies

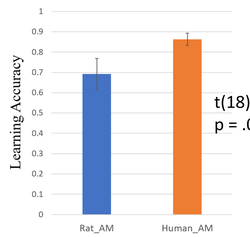
RAT LEARNER



HUMAN LEARNER

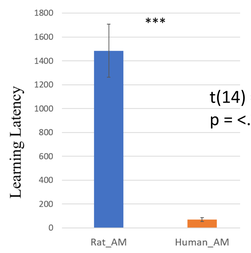


Learning Accuracy



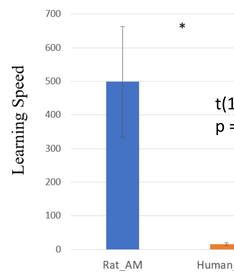
t(18) = 1.99, p = .06

Learning Latency



t(14) = 6.15, p = <.001

Learning Speed



t(14) = 2.83, p = <.05

Discussion

- We have developed a novel computational model that characterizes human and rodent learning in a cross-species sequence learning task.
- This model can capture varying learning dynamics across species (e.g., learning strategy and distinguishing learners from non-learners.)
- Most rats employ a single sequence strategy while most humans employ a two-sequence strategy.

References: (1) MacDonald et al., 2013 J. Neurosci.; (2) Umbach et al., 2020 PNAS; (3) Thavabalasingam et al., 2019 PNAS

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