The temporal context model as a description of medial temporal lobe function

Marc W. Howard
Department of Psychology
Syracuse University

introduction

Neurobiology is the ultimate in model selection.

- Neuropsychological data (e.g. Nosofsky & Zaki, 1998; Ashby *et al*, 1998)
- Physiological models focusing on NT systems (e.g. Ashby & Casale, 2004; Hasselmo & Wyble, 1997)
- Map internal model variables onto unit activity (Smith & Ratcliff, 2004)

Here we illustrate a mesoscopic approach starting with a behavioral model.

the temporal context model

A gradually changing representation of temporal context (Estes, 1955; Mensink & Raaijmakers, 1988; Murdock, Smith & Bai, 1998)

$$\mathbf{t}_i = \rho_i \mathbf{t}_{i-1} + \beta \mathbf{t}_i^{IN} \quad (1)$$

This serves as the cue in episodic recall. Combined with a competitive retrieval rule, this enables a description of recency effects across delay schedules.

The input vector $\mathbf{t}_i^{IN}$ is caused by the item presented. when an item is repeated at time r, the context retrieved by that item is:

$$\mathbf{t}_r^{IN} = \alpha_O \mathbf{t}_i^{IN} + \alpha_N \mathbf{t}_i \quad (2)$$

Associative effects are mediated by the effect items have on context (Howard & Kahana, 2002).

brain-centric modeling

The MTL is extremely important in

- Episodic recall: Neuropsychological studies, imaging
- Spatial navigation: the hippocampal place code
- Relational learning: Lesion studies, single cell recordings

These functions rely on the same hardware…do they reflect a common computational framework?

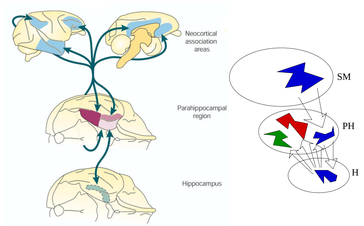
- An analogy between temporal context and a representation of position:

$$\mathbf{t}_i \propto \sum_{j=i}^{-\infty} \rho^{i-j} \mathbf{t}_j^{IN}$$

$\mathbf{t}_i$ approximates the first integral of $\mathbf{t}_i^{IN}$…position is the first integral of velocity. In spatial applications we assume $\mathbf{t}_i^{IN}$ is the instantaneous velocity.

- Relational memory effects result from contextual mixing with $\alpha_N > 0$

macroscopic mapping



- Static item vectors in ctx
- $\mathbf{t}_i$ in parahipp ctx (esp EC)
- H makes non-zero α_N

(for a detailed implementation, see Per's poster)

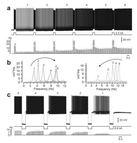
microscopic plausibility

$$\mathbf{t}_i = \rho_i \mathbf{t}_{i-1} + \beta \mathbf{t}_i^{IN}$$

Entorhinal cortex layer V…

1. Contains integrator cells
2. Receives input from head direction cells
3. Divisive inhibition to normalize (Chance *et al* 2002, *Neuron*)

…all you need to implement Eq. 1



(Egorov *et al* 2002, *Nature*)

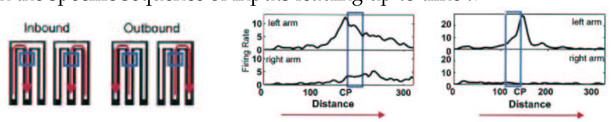
a mesoscopic approach

Basic unit of TCM is the vector—a pattern of activity across cells.

Unfortunately, most neurophysiology reports types of individual cells. Infer properties of the vector from reports of cell classes and properties of individual components from vectors.

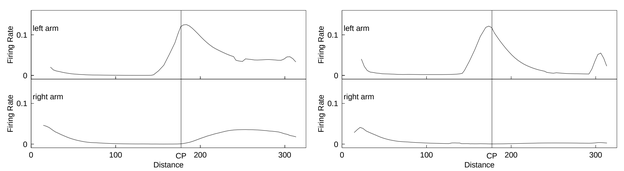
An example: retrospective coding:

- $\mathbf{t}_i$ depends on the specific sequence of inputs leading up to time i.



Frank, Wilson and Brown (2000).

- We infer the ensemble vector in EC depends on the sequence of movements.
- We can then map the vector representation of $\mathbf{t}_i$ by looking at individual components and treating them as "cells."

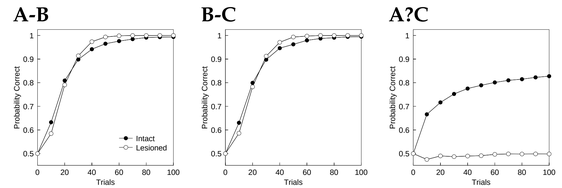


lesion studies

Bunsey and Eichenbaum (1996, *Nature*) showed that hippocampal lesions did not disrupt simple forward $A-B$ associations. They did, however, disrupt backward $B?A$ and transitive (study $A-B$ and $B-C$, test $A?C$) associations.

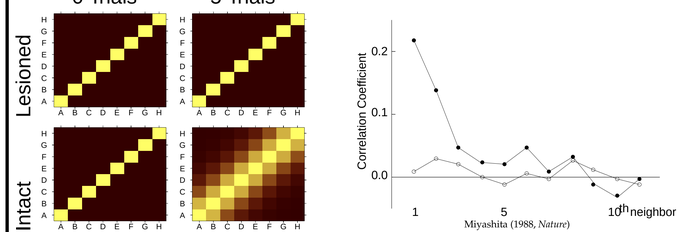
$$\mathbf{t}_r^{IN} = \alpha_O \mathbf{t}_i^{IN} + \alpha_N \mathbf{t}_i$$

We simulated hippocampal lesion by setting $\alpha_N = 0$



an intermediate stimulus representation

The ability to make "bridging" $A-C$ associations results from contextual mixing. Stimulus representations that depend on temporal context are observed in EC/IT and depend on backward connections from MTL.



references

Howard, M. W., Fotedar, M. S., Datey, A. V., & Hasselmo, M. E. (In press). The temporal context model in spatial navigation and relational learning: Toward a common explanation of medial temporal lobe function across domains. *Psychological Review*.

Howard, M. W., & Kahana, M. J. (2002). A distributed representation of temporal context. *Journal of Mathematical Psychology*, *46*(3), 269-299.

Supported by 1-R01 MH069938, 2-R01 MH55687, P50 MH60450. Set in LaTeX2e using posterboxen.sty by Per Sederberg. Thanks to Michael Kahana, who developed the first version of TCM and collaborated extensively on its development. Correspondence to marc AT memory DOT syr DOT edu. P/reprints available from http://memory.syr.edu.