SYDE 556/750

Simulating Neurobiological Systems
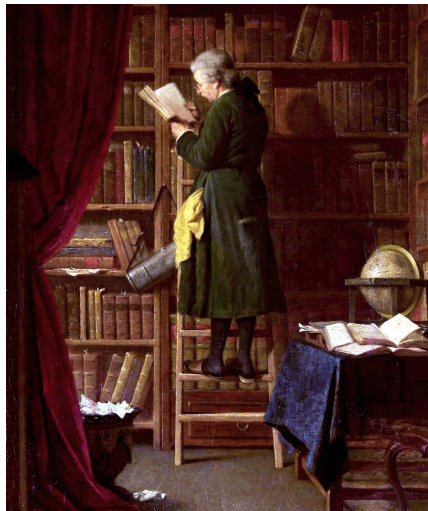**Lecture 11: The Semantic Pointer Architecture**

Chris Eliasmith

November 17 & 18, 2022

- ▶ Slide design: Andreas Stöckel
- ▶ Content: Terry Stewart, Andreas Stöckel, Chris Eliasmith

UNIVERSITY OF **WATERLOO** | **FACULTY OF ENGINEERING**

Administrative Notes – Remaining Deadlines

- **Assignment 4** – Due Nov. 18[*]

- **Assignment 5** – Due Dec. 2[*]

- **Project Presentations** – Dec. 1
  - 5-10 min. presentation (see the 'project summary document' on the website for instructions)
  - Worth 5 marks (25% of the final project) of the final project

- **Final Project** – Due Dec. 18[*]
  - Worth 20% of the final mark

[*] All deadlines are 11:59pm EDT

The Semantic Pointer Architecture (SPA)

- **SPA**

    - Semantics

    - Syntax

    - Control

    - Learning and memory
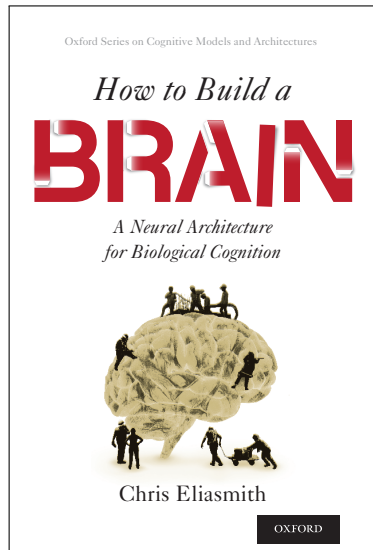
Shallow Versus Deep Semantics

TREE

`0x54 0x52 0x45 0x45`

Shallow semantics (relational)

$\forall x\,$**is_a**$(x, \text{PINE}) \rightarrow$ **is_a**$(x, \text{TREE}) \land$ **has**$(x, \text{NEEDLES}) \land$ **is**$(x, \text{EVERGREEN})$,

$\forall x\,$**is_a**$(x, \text{TREE}) \rightarrow$ **is_a**(x, PLANT),

$\forall x\,$**is_a**$(x, \text{PLANT}) \rightarrow$ **is**(x, ALIVE).

Deep semantics ("subjective experience")

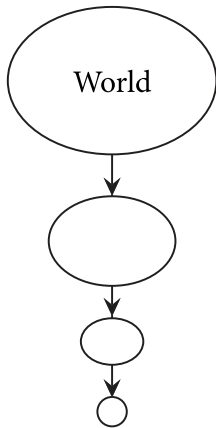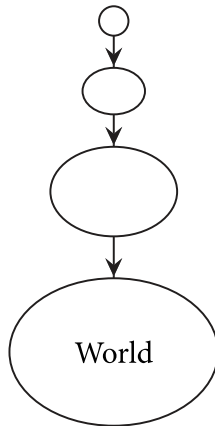# Deep Semantic in Perception: Dereferencing
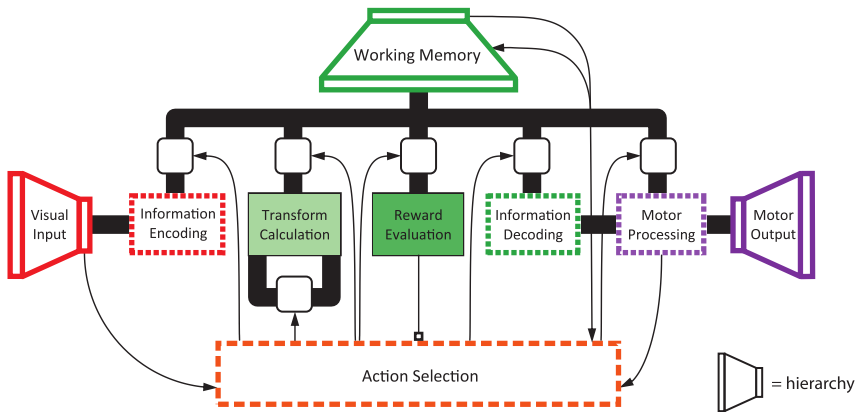
A.

B.

C.

D.
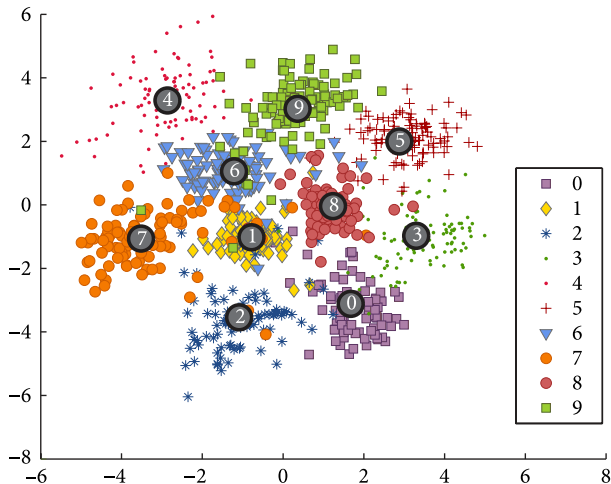
Perception vs. Action

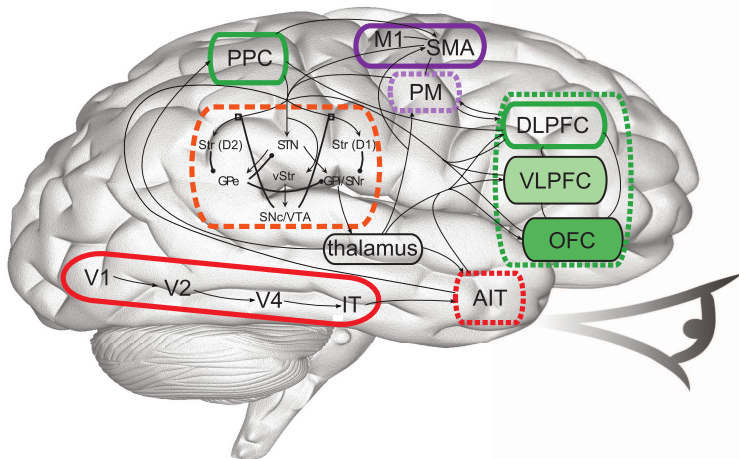Perception

Motor Control

World

World

World → Representation

Representation → World

Spaun – Semantic Pointer Architecture Unified Network (I)

Spaun – Semantic Pointer Architecture Unified Network (II)

Nengo SPA Example (I)

Nengo SPA Example (II)
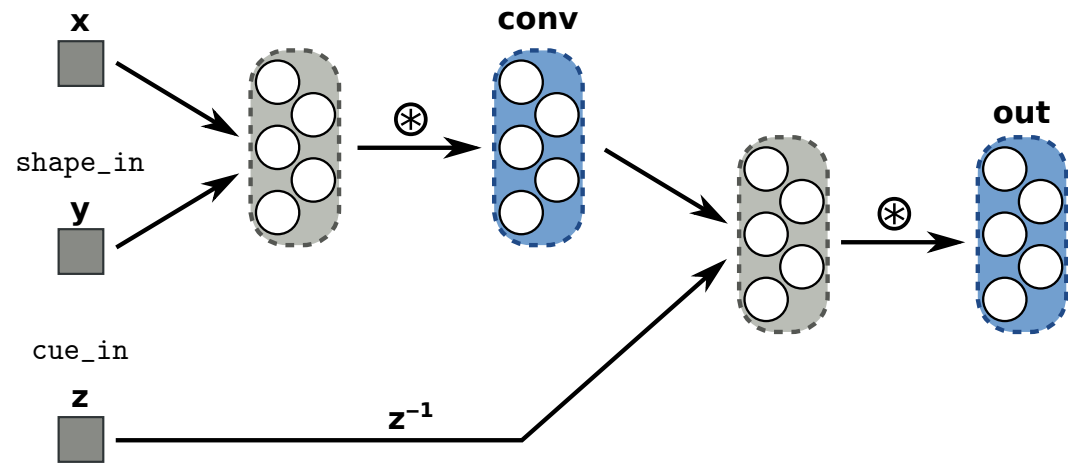

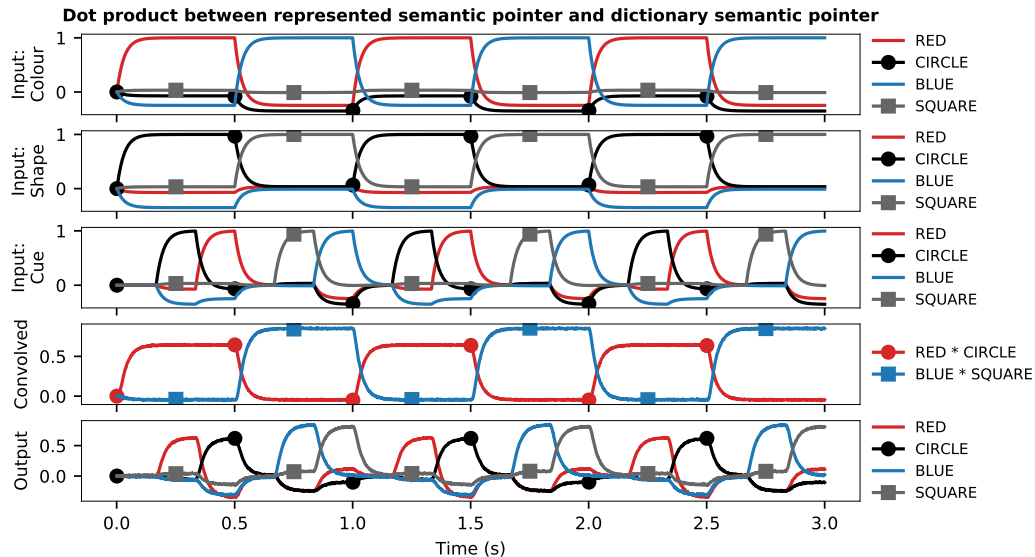**Dot product between represented semantic pointer and dictionary semantic pointer**

Recency and Primacy Experiment

Experiment: Remember this list (presented one at a time)

1. robot
2. teflon
3. kettlemaking
4. big-league
5. troubleshooter

6. conglomerates
7. waxberries
8. electrograph
9. overjoyous
10. unquailing

Recency and Primacy Data

Typical Forward Serial Recall Curves
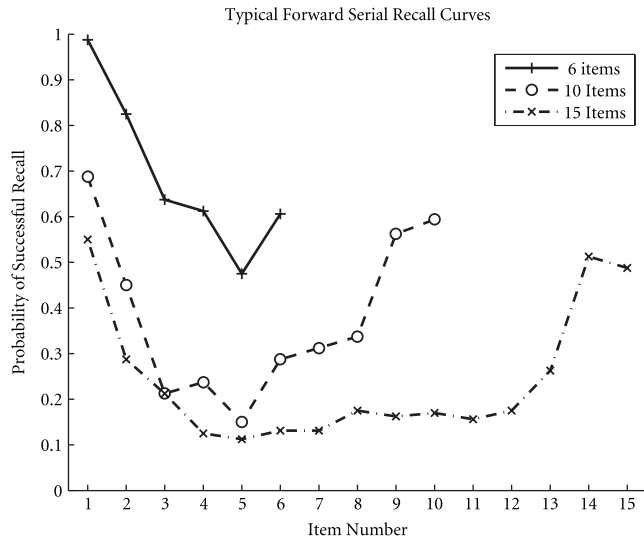
Ordinal Serial Encoding (OSE) Model
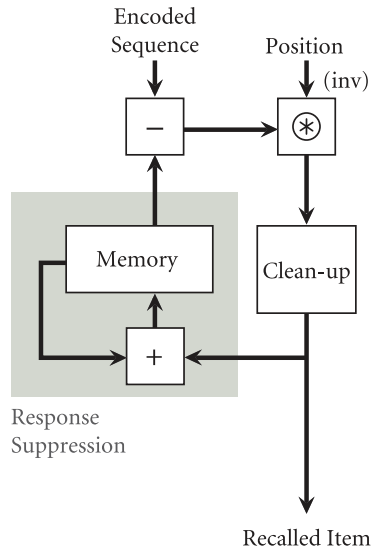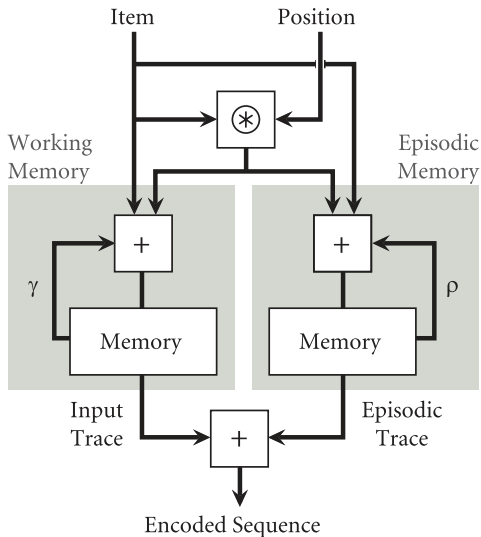
Ordinal Serial Encoding (OSE) Model: Experiment

Basal Ganglia (BG)

Striatum
- Caudate nucleus
- Putamen

Globus pallidus

Subthalamic nucleus

Substantia nigra

Biological Psychology 6e, Figure 11.18

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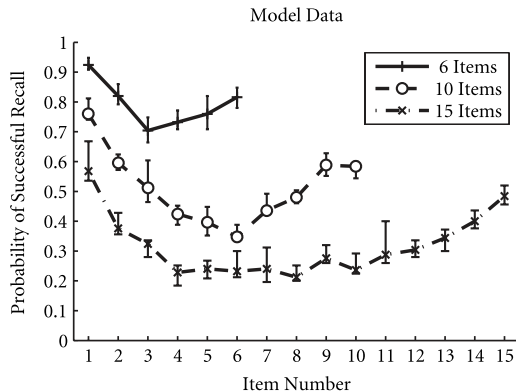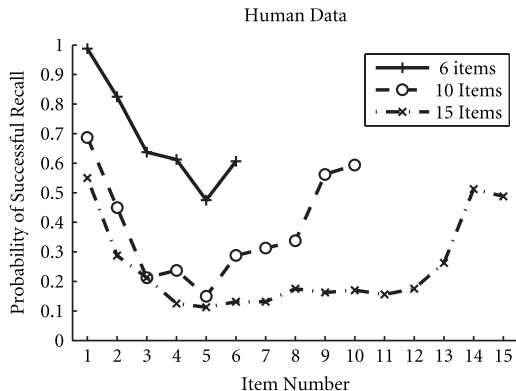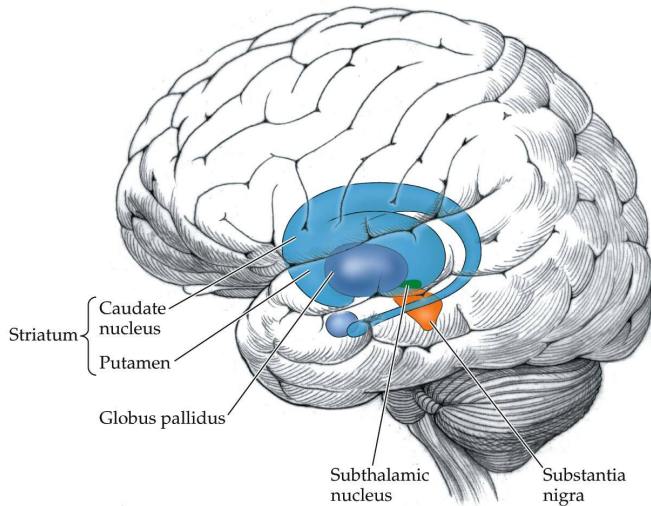
Clinical Evidence for the Role of the BG in Action Selection

Parkinson's disease

- ▶ Neurons in the substantia nigra die off

- ▶ Difficult to trigger actions to start

- ▶ Usually physical actions
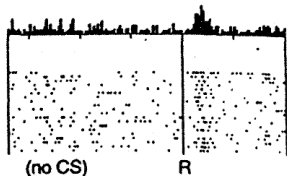
- ▶ Cognitive effects in later stages

Huntingtons's disease

- ▶ Neurons in the striatum die off

- ▶ Actions triggered inappropriately

- ▶ Small uncontrollable movements
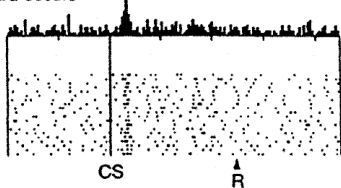
- ▶ Trouble sequencing cognitive actions

Neurophysiological Evidence for the Role of the BG in Action Selection

▶ Role in reinforcement learning

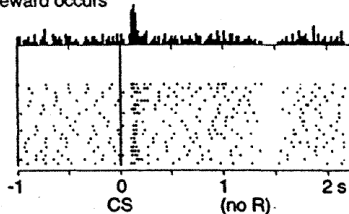▶ Dopamine levels map onto reward prediction error

No prediction
Reward occurs

(no CS)   R

Reward predicted
Reward occurs

CS   R

Reward predicted
No reward occurs

-1   0   1   2 s
    CS   (no R)

Microcircuitry of the Basal Ganglia
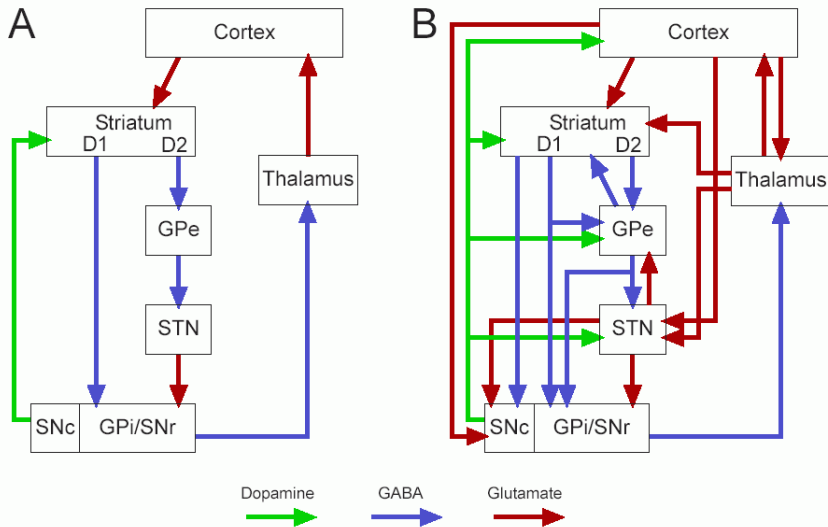
Simplified Model
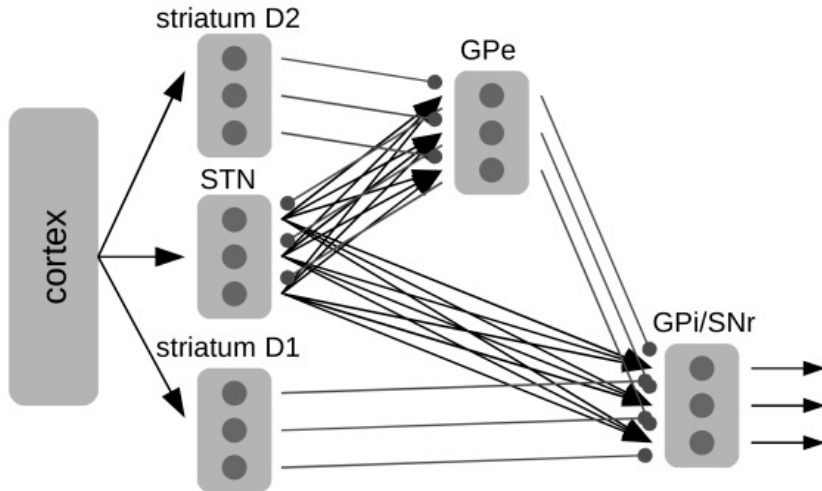
The Cortex-Basal Ganglia-Thalamus loop

Image sources

Title slide
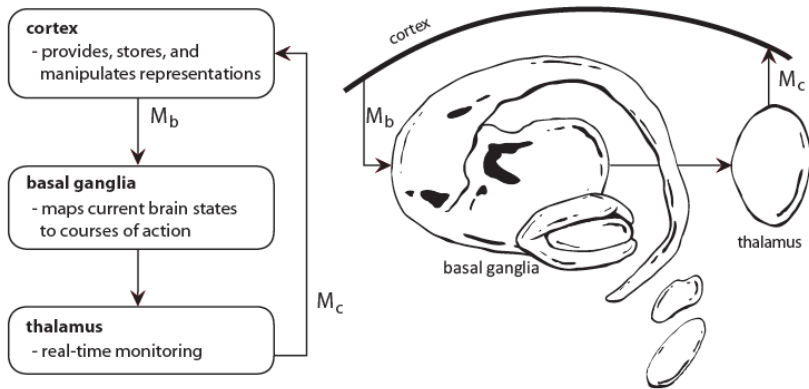*Librarian (In a library)*, between 1850 and 1866, Georg Reimer
Wikimedia.