SYDE 556/750

Simulating Neurobiological Systems
Lecture 11: The Semantic Pointer Architecture

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March 24 & 26, 2020

UNIVERSITY OF WATERLOO | FACULTY OF ENGINEERING

Administrative Notes – Remaining Deadlines

- **Assignment 4** – Due Tuesday, Mar. 24* (today!)
  - Worth 10% of the final mark
- **Interim Project Report** – Due Thursday, Apr. 2* (no late submission!)
  - One to two pages maximum; see the website for instructions
  - Not marked; either 0% (not submitted) or 100% (reasonable document submitted)
  - Worth 10 marks (25% of the final project) of the final project
- **Final Project** – Due Wednesday, Apr. 15*
  - Worth 40% of the final mark

* All deadlines are 11:59pm EDT

Shallow Versus Deep Semantics

TREE

0x54 0x52 0x45 0x45

Shallow semantics (relational)

$$\forall x \, \mathbf{is_a}(x, \texttt{PINE}) \rightarrow \mathbf{is_a}(x, \texttt{TREE}) \wedge \mathbf{has}(x, \texttt{NEEDLES}) \wedge \mathbf{is}(x, \texttt{EVERGREEN}),$$

$$\forall x \, \mathbf{is_a}(x, \texttt{TREE}) \rightarrow \mathbf{is_a}(x, \texttt{PLANT}),$$

$$\forall x \, \mathbf{is_a}(x, \texttt{PLANT}) \rightarrow \mathbf{is}(x, \texttt{ALIVE}).$$

Deep semantics ("subjective experience")

Deep Semantic in Perception: Visual Processing Hierarchy

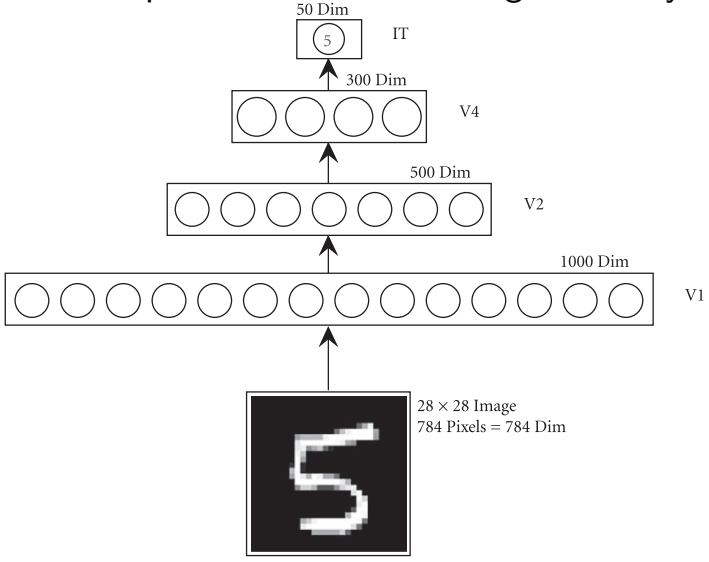


Image Sources. Eliasmith, "How to Build a Brain", 2013, Figure 3.4

Deep Semantic in Perception: Dereferencing

A.

B.

C.

D.

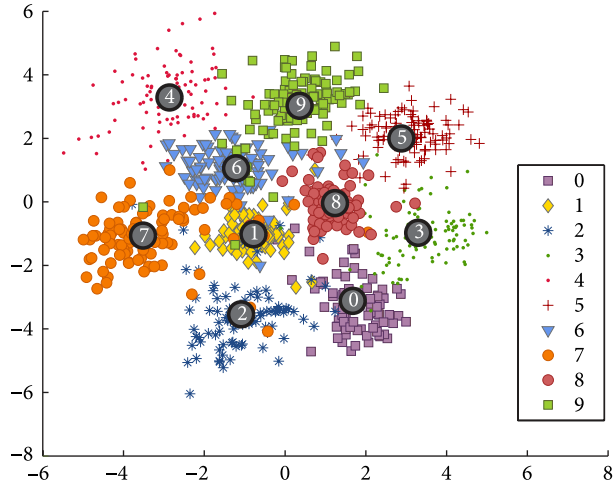
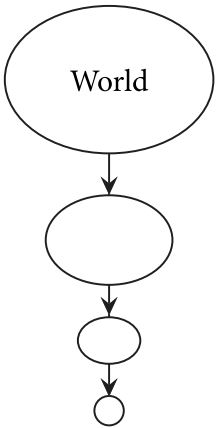


Image Sources. Eliasmith, "How to Build a Brain", 2013, Figure 3.7

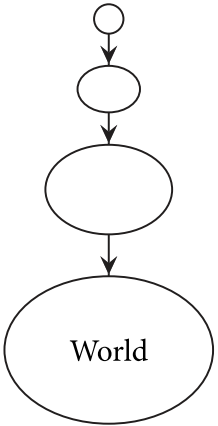
Perception vs. Action

Perception



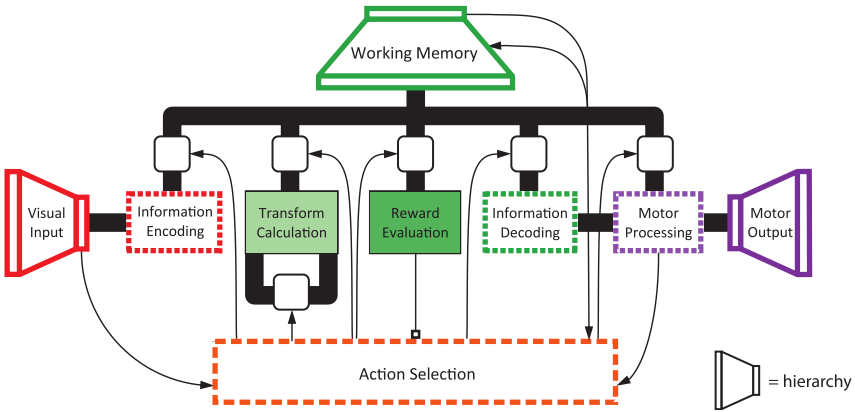
World → Representation

Motor Control

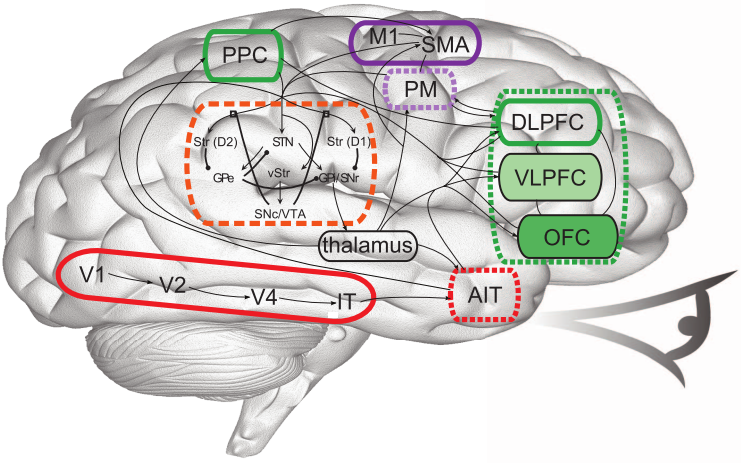


Representation → World

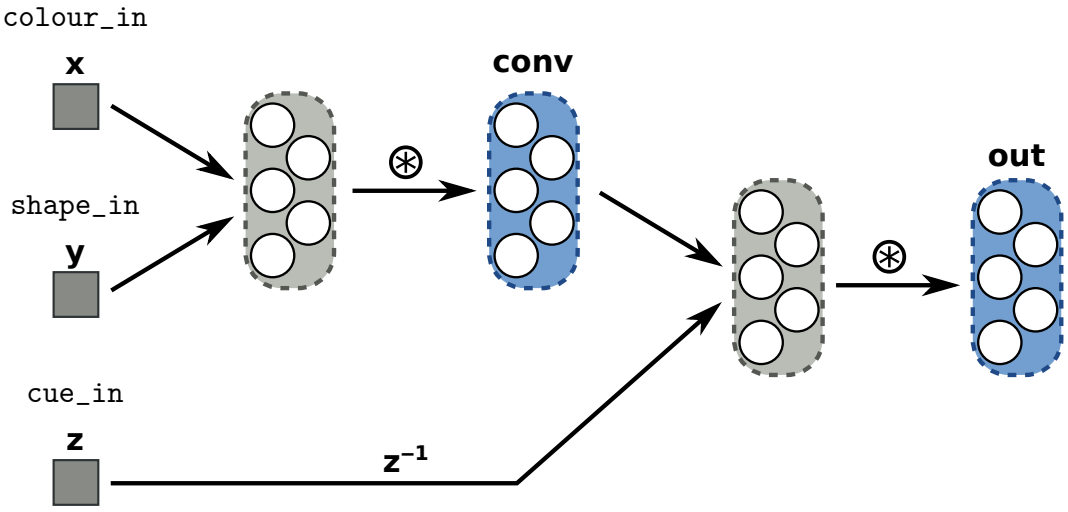
Spaun – Semantic Pointer Architecture Unified Network (I)



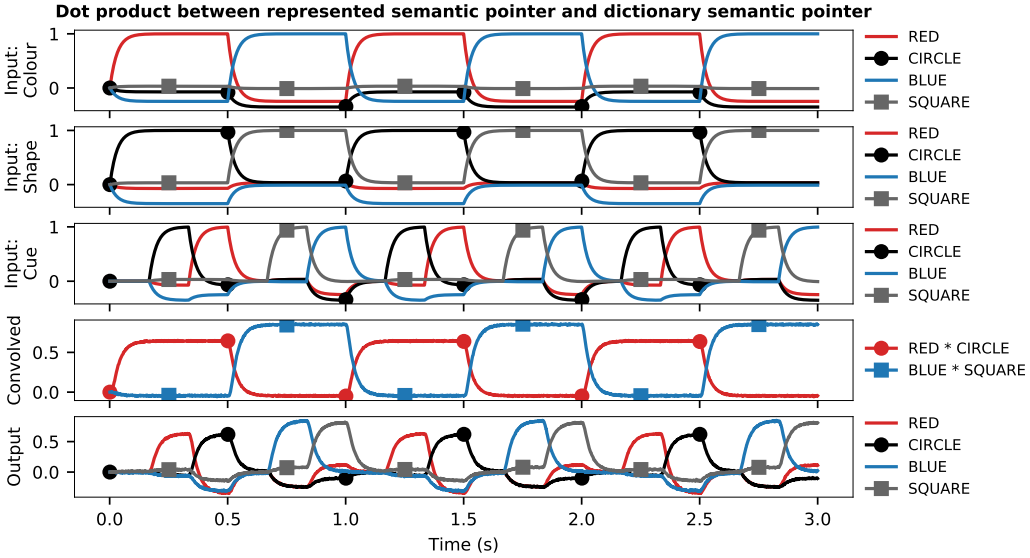
Spaun – Semantic Pointer Architecture Unified Network (II)



Nengo SPA Example (I)



Nengo SPA Example (II)

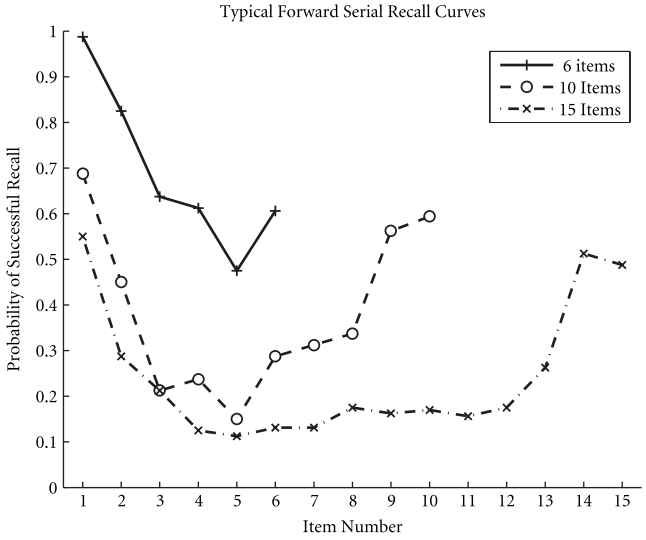


Recency and Primacy Experiment

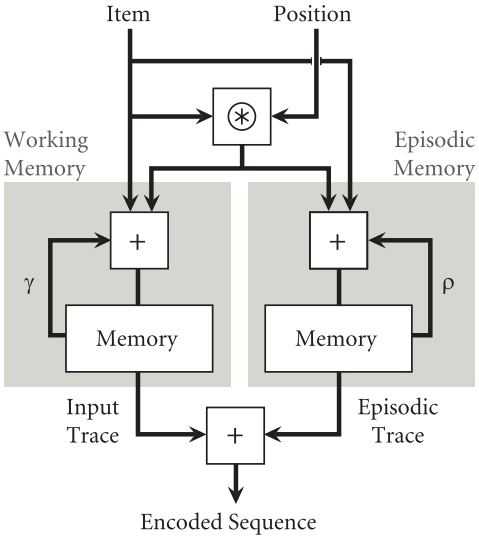
Experiment: Remember this list (presented one at a time)

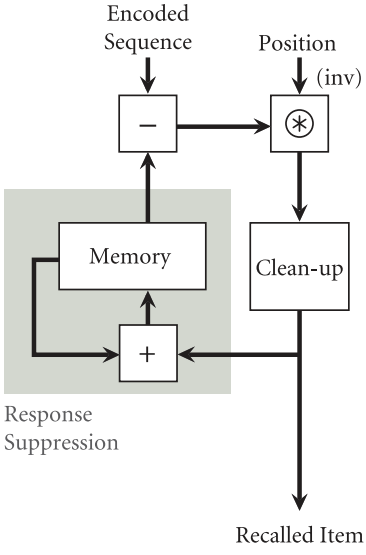
1. robot
2. teflon
3. kettlemaking
4. big-league
5. troubleshooter
6. conglomerates
7. waxberries
8. electrograph
9. overjoyous
10. unquailing

Recency and Primacy Data

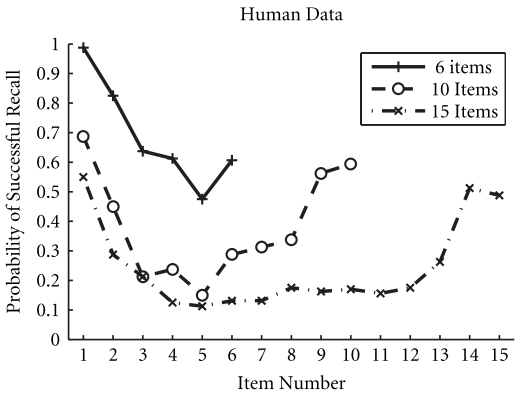


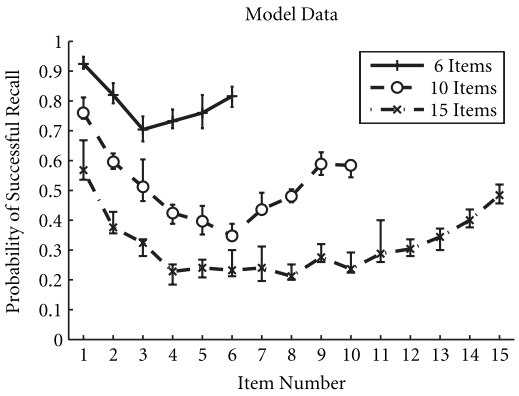
Ordinal Serial Encoding (OSE) Model



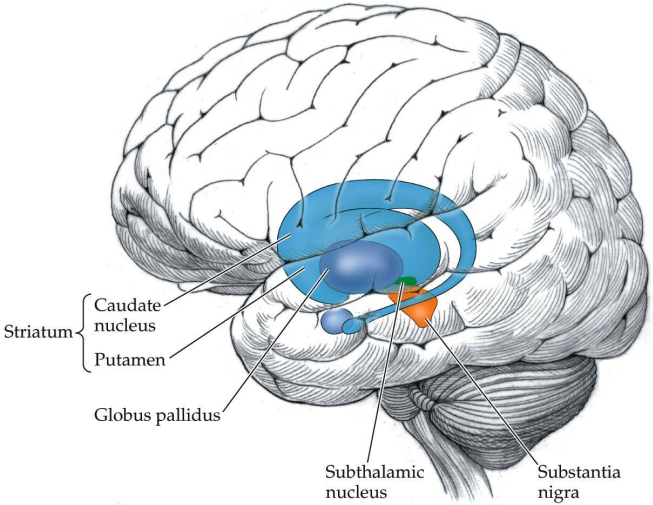


Ordinal Serial Encoding (OSE) Model: Experiment





Basal Ganglia (BG)



***Biological Psychology 6e*, Figure 11.18**

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Clinical Evidence for the Role of the BG in Action Selection

Parkinson's disease

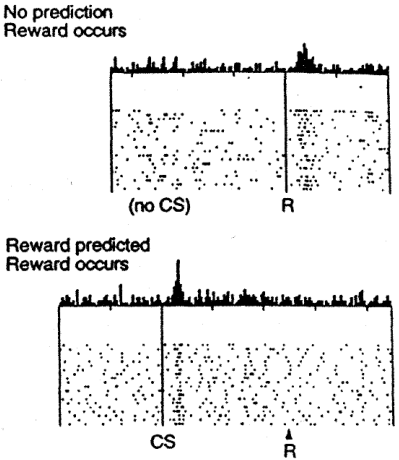
- Neurons in the substantia nigra die off
- Difficult to trigger actions to start
- Usually physical actions
- Cognitive effects in later stages

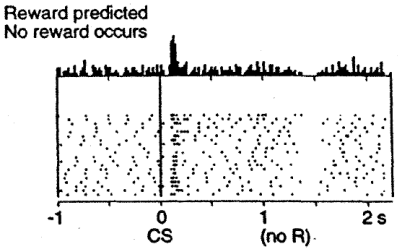
Huntingtons's disease

- Neurons in the striatum die off
- Actions triggered inappropriately
- Small uncontrollable movements
- Trouble sequencing cognitive actions

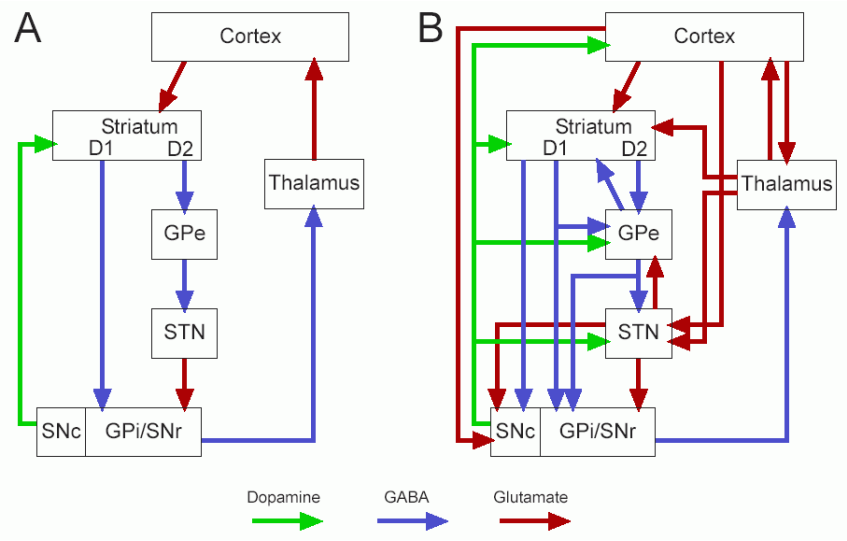
Neurophysiological Evidence for the Role of the BG in Action Selection

- Role in reinforcement learning
- Dopamine levels map onto reward prediction error





Microcircuitry of the Basal Ganglia



Simplified Model

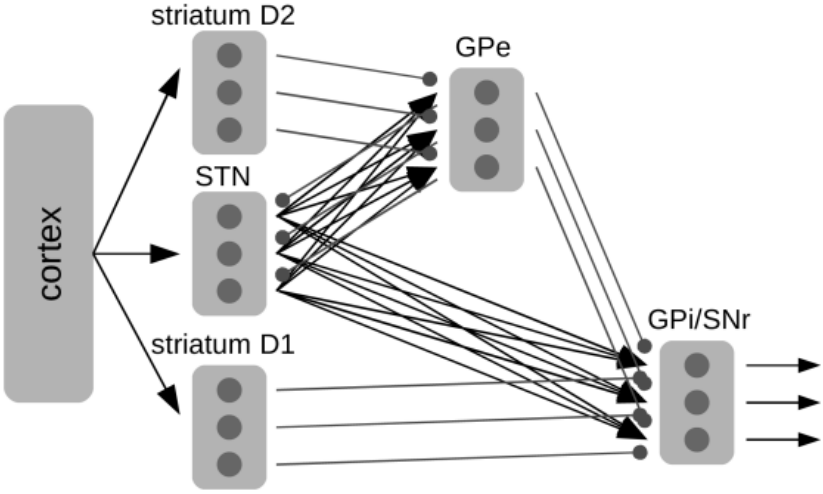
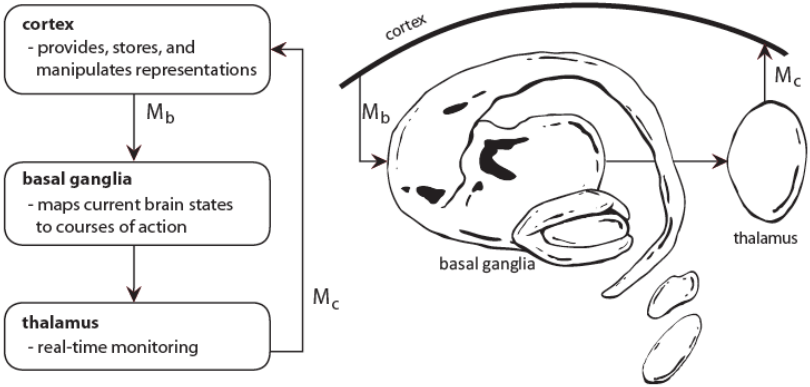
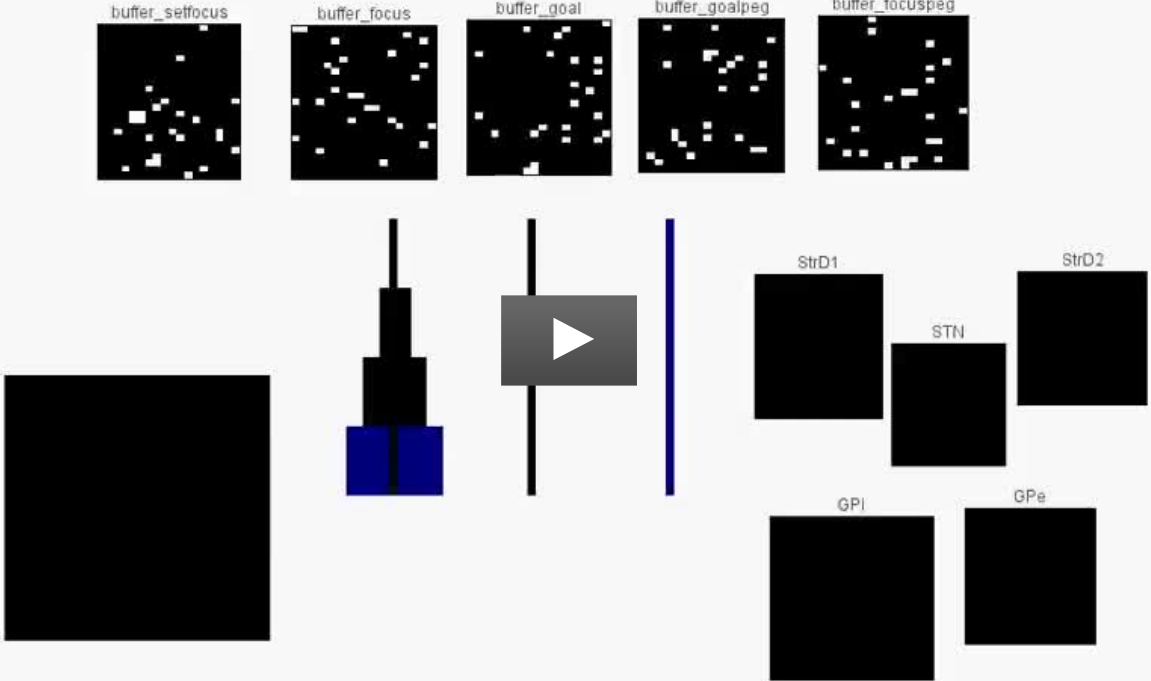


Image Sources. Gurney, Prescott, and Redgrave, *Model of Action Selection in the Basal Ganglia, 2001*

The Cortex-Basal Ganglia-Thalamus loop

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StrD1
StrD2
STN
GPI
GPe

Image sources

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