Fronto-parietal attention/Working memory networks

DLPFC  IPS

FEF
Integration Functions in the Frontal Lobe

Kroger, Sabb, Fales, Bookheimer, Cohen, Holyoak 2002
Ventral PFC- regulation, response inhibition
Frontal Lobe Memory Syndromes

- Intact encoding/consolidation of new memories
- Poor retrieval
  - improve with cues like category
- Poor initial organization
- Proactive interference
  - Build-up of inhibition over time
  - Release from proactive interference following delay
- Severe cases: confabulation; inability to distinguish true memory from current thought
- Prospective memory deficits
- Working memory impairment
Primary causes of FLMI

- Traumatic Brain Injury
  - Shape of head accelerates frontal injury
  - Tearing and shearing of WM connections
  - Concussive injuries
  - Hematomas, subarachnoid hemorrhages
- Stroke
  - ACA territory
- Small vessel cerebrovascular disease
- Fronto-temporal Dementia
- Heart attack; reduced CBF; diabetes, etc
Fronto-Temporal Dementia
Fronto-Striatal Circuits

Adapted from Alexander GE, DeLong MR, Strick PL 1986
Parallel Memory Systems

- Episodic Memory- Hippocampal based
- Procedural and “Habit” learning system: Basal Ganglia
  - Reward system effects on learning-ventral striatum
- Frontal lobe contributions
  - Retrieval systems
  - Organization of input
- Priming
  - Repetition priming/sensory based traces
  - Frontal contributions to effortful learning/priming
Patient H.M. can learn…..

• Was able to navigate around his (new) environment, eventually.
• Could learn new skills: initially, motor skills; ultimately found to include cognitive skills
• Eg mirror reading (see next slide)
• Could perform the tower of Hanoi in the optimal number of moves; but had to be explained the directions repeatedly; no memory of having seen it before
• Thus there was some unconscious, implicit learning that was conceptual in nature
Implicit learning and dorsal striatum

- Dorsal striatum (Ca/Pu) is implicated in implicit or “habit” learning (Knowlton and Squire)

- Language acquisition and social learning are thought to rely on implicit learning mechanisms
  - Probabilistic learning tasks (vs. deterministic) are implicit, subconscious, and rely on dorsal striatum
Imaging the striatal learning system: Learning a new skill

- Mirror-reading: (Poldrack et al)

- College students were taught to read mirror-reversed text for ~5 hours
- Scanned before and after learning using fMRI
- Activity in striatum during learning
- Normal in HC lesioned patients
Knowlton and Squire

- Performed a probabilistic learning task in Parkinson’s patients and amnestic patients: Weather Prediction Task
- In this task subjects learn an association between a stimulus (a playing card) and an outcome (rain or shine)
- Relationship was probabilistic, not deterministic; 66% probability of an outcome
- Subjects could not memorize the associations, and ultimately guessed
- However their behavior showed a learning curve despite no explicit knowledge of learning
Learning concepts without consciousness

a  Feedback-based task

RAIN?

Subject presses button for ‘RAIN’ or ‘SUNSHINE’

SUNSHINE

b  Paired-associate task

SUNSHINE

Subject presses button to denote stimulus onset

SUNSHINE
• Amnesic patients learned the associations (without awareness)
• Parkinson’s patients did not
• Requires hundreds of trials
• Testing of explicit memory results in chance
• Behavior shows learning
• Considered an implicit, habit based learning system
• What other skills do you learn this way?
Implicit learning
Basal Ganglia and learning

• What else is learned implicitly?
  – Language learning and grammar: based on probabilistic word boundaries and repetition to learn syntactic structures
  – Social skills: how close to stand to people, how loud to talk, where to stand in an elevator, how much eye contact, etc
Striatum is Involved in Language & Communication

- Artificial grammar learning (Lieberman et al., 2004)
- Subjects given sequences of letters with probabilistic sequences
- Presented novel sequences that follow the same rules
- Subjects can correctly classify them as right or wrong without knowing the rules or having learned the specific examples!

Lieberman et al., 2004 *J Cog Neuro*
Implicit Language Learning

M. Dapreto, A. Scott

- **3 Miniature Artificial Languages**
  - Unstressed (Transitional Probabilities only)
  - Stressed (Transitional Probabilities & Prosodic Cues)
  - Random (No Transitional Probabilities OR Prosodic Cues)

![Diagram showing the sequence of words in each language block:]

- **Block 1**: `pabiku daropi golatu tibudo`
  - Each word repeats 3 times

- **Block 2**: `novuka pofimu vikoga bafugi`
  - Each word repeats 15 times

- **Block 3**: `lidura vorifa manuto nimolu`
  - Each word repeats 45 times during the condition
Implicit Language Learning

- Stressed Language: 144 s
- Unstressed Language: 30 s
- Random Syllables: 144 s

TIME (seconds)
Implicit Language Learning

- 2 languages (Stressed & Unstressed) vs. rest
- Absence of activity in caudate, mPFC and left IFG in ASDs
The area shown in orange is the ventral striatum, also known as the nucleus accumbens or the accumbens area. This region is implicated in processing rewards. Craving drugs, gambling, getting a food reward, sex, getting revenge, seeing someone smile—all elicit activity in this area. It is strongly connected to the frontal lobe and appears to respond best to the difference between the reward you get and what you expect.
Reward-Related Learning and Prediction Error

- DA inputs to VS and PFC signal Prediction Error (PE)
  - PE is the difference between expected and actual reward
  - Used to update expected future rewards associated with that stimulus
- Learning occurs through convergence of PE on 0 as expected reward matches actual reward
Implicit Learning and Reward

- Probabilistic Classification Task
- Reported by Knowlton and Squires - impaired in PD, intact in amnesia
- Inversely related to hippocampal activity
- Reward variant - social vs. monetary
  - Stimuli predict a given outcome (1 or 2); 50% deterministic, 50% random
  - Reward and Cognitive (Correct / Incorrect) feedback

Adults: BG activity during probabilistic learning

Source: D. Ghahremani
Risk taking behavior: Reward response (left) - high risk option (right)
Response to Rewards

Typical | Autism | Typical > Autism

Every occurrence of a reward (any type) vs. no-reward
Reward response in VS

Magnitude (mean %)

Social

Monetary

TD

ASD
Effect of rewards on implicit learning
Dorsal Striatum deficits in ASD during implicit learning

Typical children > ASD children
Variation in VS activity in typical children predicts social reciprocity

![Graph showing the relationship between PE Social Deterministic Rewards and Social Responsiveness Scale Score. The graph displays a negative correlation, with dots scattered along a downward sloping line, indicating a decrease in PE Social Deterministic Rewards as Social Responsiveness Scale Score increases. There is also an image of a brain scan with a highlighted region on the right side.]