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Higher Level Cognition: What's Missing

- Planning
- Reasoning
- Decision-making
- Emotion
- Consciousness, sense of self
- Free will
- Social interaction

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The Range of Frontal Functions

Activation-based working memory Monkey electrophysiology.

Inhibition Stroop: Difficulty inhibiting prepotent response.

Flexibility Continue with same response after task changes, *perseveration*.

Fluency Difficulty generating variety of responses.

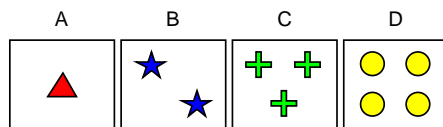
Executive control Probs w/ goal-directed planning, coordinating.

Monitoring/evaluation e.g., Error-monitoring.

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Dynamic Categorization Tasks

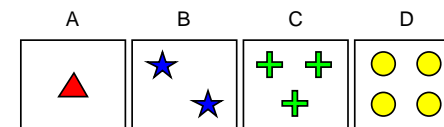
Wisconsin Card Sort



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Dynamic Categorization Tasks

Wisconsin Card Sort

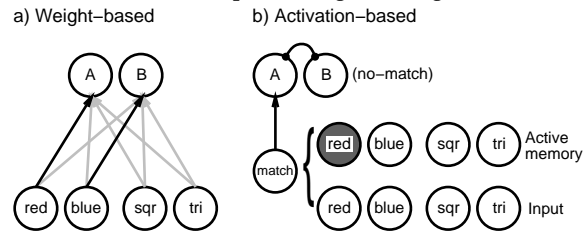


Experimental task (like Stroop), but captures some essential aspects of higher level cognition.

Frontal patients perseverate with the first rule.

5 Computational Approach to Higher Level Cognition

Key Idea: Activation-based processing (vs weight-based):



Advantages:

- Flexibility.
- Accessibility.
- Impact.

6 "Frontal Tasks"

- Stroop: Ability to override prepotent response (word reading) in favor of currently relevant task (color naming) – requires top-down control.
- Activation based directing of attention.
- "Prefrontal control" not just for overriding long term associations like word reading, but also for the ability to quickly change attention in an online fashion in response to changing task demands: UPDATING.

7 Card Sorting Tasks

- Relevant to everyday life, or just to this peculiar task?
- Good measure of online thinking & problem solving: The ability to flexibly consider different possibilities to guide thinking and behavior.

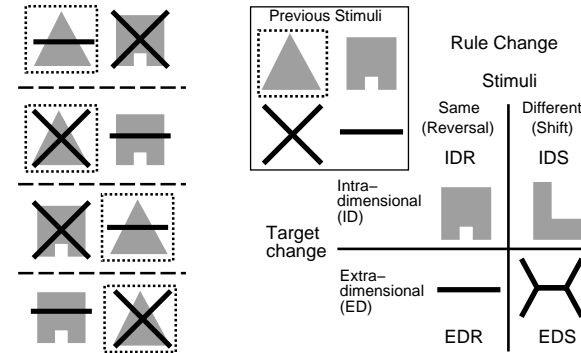
8 Card Sorting Tasks

- Q: In what situations do we need to consider/represent different rules in mind and have the ability to flexibly update/maintain them until one works well?
- A: right now! Thinking, Learning. I'm asking you a question, you consider an alternative (e.g., never: card sorting tasks are dumb).
- You then evaluate the quality of what you're holding in mind to see if it makes sense and is likely to produce a good outcome.
- If yes maintain info for further processing, if not switch to different possibilities.

- Science: hypothesis formulation from observed experimental data.

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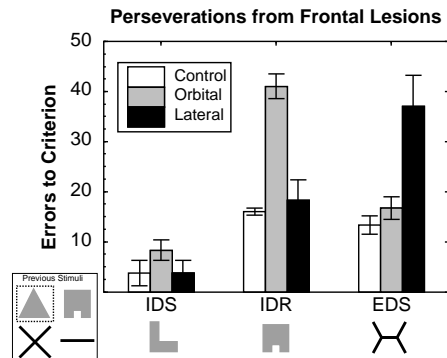
Dynamic Categorization Tasks: ID/ED task



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ID/ED and Frontal Damage

(Dias, Robbins & Roberts (1997), *J Neurosci*)



Original interpretation: Orbital = affective inhibition,
Lateral = attentional selection.

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Alternative Account

(O'Reilly, Noelle, Braver & Cohen (2002), *Cerebral Cortex*)

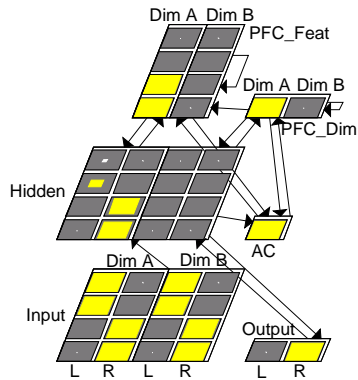
Orbital PFC represents detailed **features**.
Lateral PFC represents abstract **dimensions**.

Activation-based PFC processing facilitates rule switch:
Orbital = switch to new features (IDR).
Lateral = switch to new dimension (EDS).

Perseverations = weight-based processing in absence of PFC.

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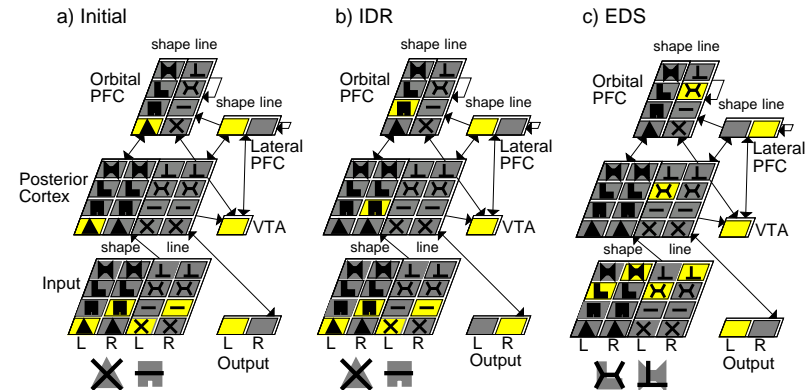
ID/ED Model



Activation limited in cortex: attention. PFC provides top-down bias. VTA = adaptive critic, causes PFC updating w/ reward.

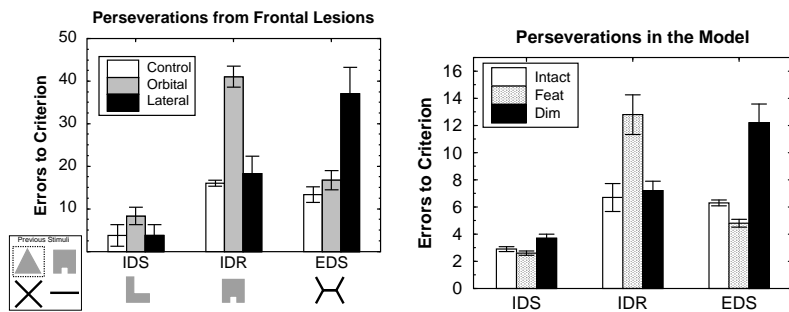
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IDR, EDS in the Model



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Model Data



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Advantages of ID/ED model

- PFC reps are not clamped as in Stroop – updated in response to changing task demands.
- Nice fit and explanation of complex monkey data.
- Shows how working memory and cognitive control may be two sides of the same coin: activation based memory is not just memory but also biases activity elsewhere in the brain (posterior).

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Limitations of ID/ED model

- Repts not clamped, but still not learned – one to one connectivity from HL.
- Distinction between OFC = features & DLPFC = dimensions may be too convenient: observed dissociation; not much evidence of OFC-features.

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Limitations of ID/ED model

- Doesn't distinguish b/w updating and maintenance systems.
- Goal/Subgoal requires *selective* updating with concurrent maintenance of task relevant info.
- Updating system thought to involve the BG and DA, damaged in PD,SZ and lead to "frontal-like" impairments in Stroop, WCST, etc.

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Goal/Subgoal Hierarchical Structure

1. Open fridge.
2. Get food items.
3. Close fridge.
4. Get bread from cupboard

Update these subgoals to guide actions, but to guide the ordering of subgoals themselves, need to maintain overall goal of task (Make sandwich)

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A Unified Activation-based Account

Central frontal mechanisms:

Activation-based working memory Frontal neurons maintain actively over delays.

Monitoring/evaluation e.g., Error-monitoring, critical for dopaminergic modulation.

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A Unified Activation-based Account

Inhibition Need to maintain top-down activation for weaker task.

Flexibility Dynamics of activation-based more rapid than weight-based.

Fluency Only problem w/ novel categories of responses — need top-down support to overcome prepotent categories.

Executive control Maintain & update plans / goals over time, avoid distraction.

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