

Ch 12. Executive Functions and Frontal Lobes

Cognitive Neuroscience: The Biology of the Mind, 2nd Ed.,
M. S. Gazzaniga, R. B. Ivry, and G. R. Mangun, Norton, 2002.

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Introduction

- W.R. – astrocytoma
- The processes essential for goal-oriented behavior
- Monitoring the success of ongoing actions – executive functions
- In the prefrontal cortex

Contents

- Subdivisions of the frontal lobes
- The lateral prefrontal cortex and working memory
- The prefrontal cortex participates in other memory domains
- Component analysis of prefrontal cortex
- Goal-oriented behavior

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Subdivisions of the Frontal Lobes

Prefrontal Cortex

- The 3 major subdivisions
 - ◆ Lateral prefrontal cortex
 - ◆ Ventromedial prefrontal cortex
 - ◆ Anterior cingulate gyrus
- About 1/3 of the brain
- Projections to everywhere – excellent position to coordinate processing across wide regions of the CNS

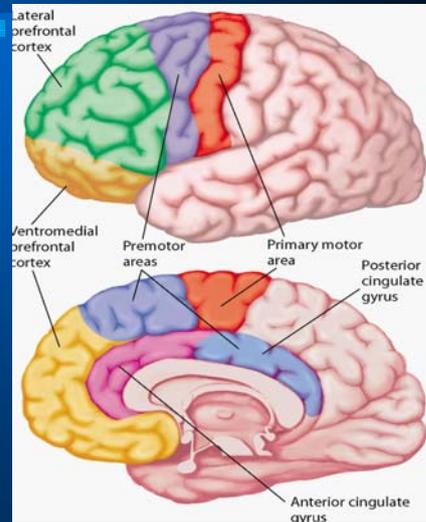


Fig. 12.1: The areas of the frontal lobe.

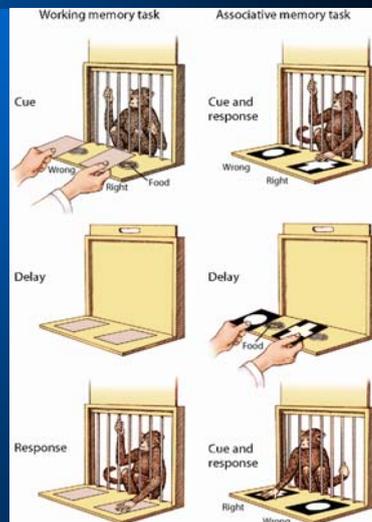
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The Lateral Prefrontal Cortex and Working Memory

Working memory vs. associative memory

- Working memory refers to transient representations of task-relevant information.
- The lateral prefrontal cortex constitutes a major component of the working memory system.
- Long-term memory is required in the associative memory task.

Fig. 12.3: Monkeys with prefrontal lesions demonstrate selective impairment on the working memory delayed-response task.



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Working memory vs. associative memory / Human studies of working memory (1/2)

- Piaget's Object Permanence Test is similar to the delay-response task.
- "Out of sight, out of mind" – Deep relation with the frontal lobes
- Wisconsin Card Sorting Task – Perseveration
- Both tasks need working memory retaining previous responses.

Fig. 12.4: Patients with damage in the lateral prefrontal cortex have difficulty on the Wisconsin Card Sorting Task.



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Working memory vs. associative memory / Human studies of working memory (2/2)

- fMRI study revealed that lateral frontal activation increased during a working memory task.
- But task-related activation is also observed across many cortical areas.

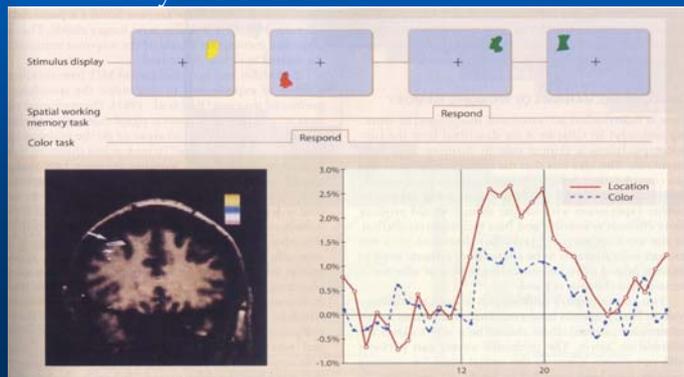


Fig. 12.5: Lateral prefrontal activation revealed by fMRI.

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Working memory vs. associative memory / Cellular mechanisms of working memory (1/4)

- Prefrontal cortex can access stored information and keep the information active – these are working memory systems conditions.
- Prefrontal neurons show sustained activity during delayed-response tasks.

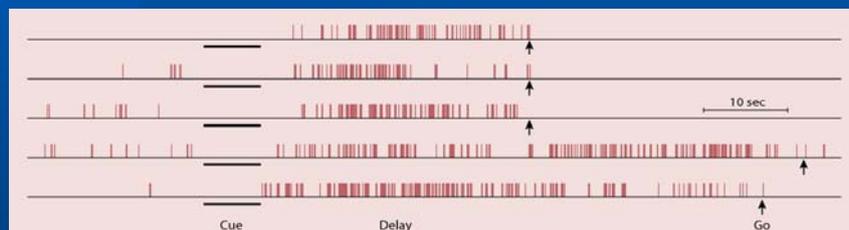


Fig. 12.6: Prefrontal neurons can show sustained activity during delayed-response tasks.

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Working memory vs. associative memory / Cellular mechanisms of working memory (2/4)

- Do prefrontal neurons simply provide a generic signal that supports representations in other cortical areas, or do the neurons code specific stimulus features?
- Cells in the prefrontal cortex exhibit selectivity in terms of stimulus attributes.

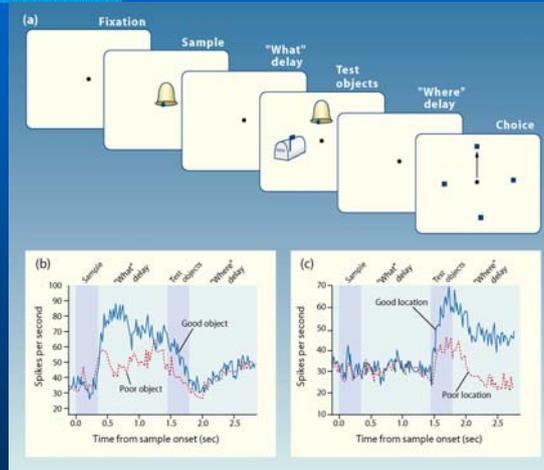


Fig. 12.7: Coding of “what” and “where” information in single neurons of the prefrontal cortex in the macaque.
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Working memory vs. associative memory / Cellular mechanisms of working memory (3/4)

- Alternative: Prefrontal areas are a temporary repository for representations accessed from other neural sites.

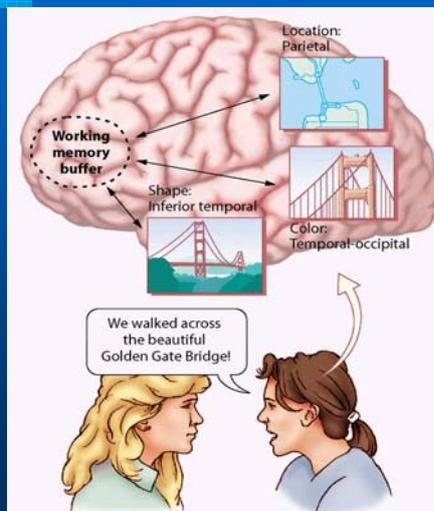
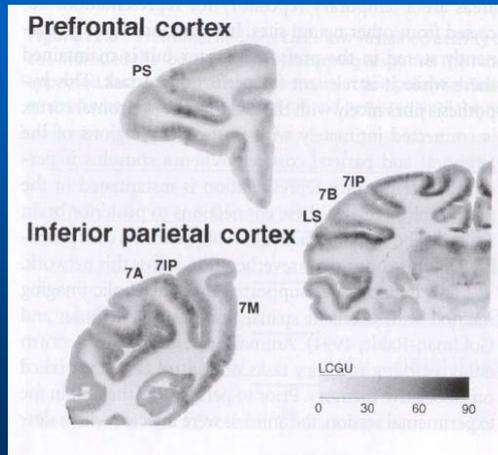


Fig. 12.8: Lateral prefrontal cortex may provide a transient buffer for sustaining information stored in other cortical regions.

Working memory vs. associative memory / Cellular mechanisms of working memory (4/4)

- Glucose utilization is correlated with working memory task performance.
- The degree of prefrontal metabolism depended on task difficulty.

Fig. 12.9: A radioactive tracer can reveal correlated activity in the prefrontal and inferior parietal cortex during a spatial working memory task.



The Prefrontal Cortex Participates in Other Memory Domains

The Frontal Lobes and the Temporal Organization of Memory – Recency Memory

- Recency memory – an ability to organize and segregate events in memory
- Recency memory is impaired in patients with prefrontal lesions.

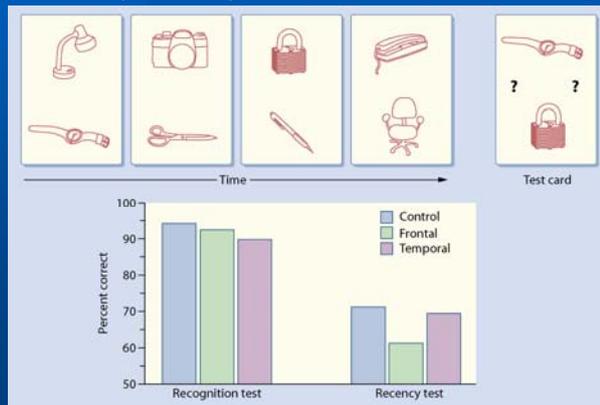


Fig. 12.10: Recency memory is impaired in patients with prefrontal lesions. **(TOP)** In the item recognition task, only one object had appeared previously. **(Bottom)**

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Source Memory

- Source memory refers to knowledge concerning the source of information or the context in which the information was learned.
- Source memory depends on the integrity of the frontal lobes.
- There was a dissociation between recall and source memory tasks.
- Item memory and source memory are dissociated.

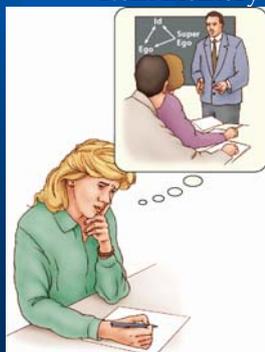
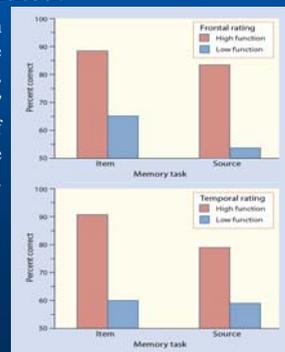


Fig. 12.11: Source memory refers to knowledge concerning the source of information or the context in which the information was learned.

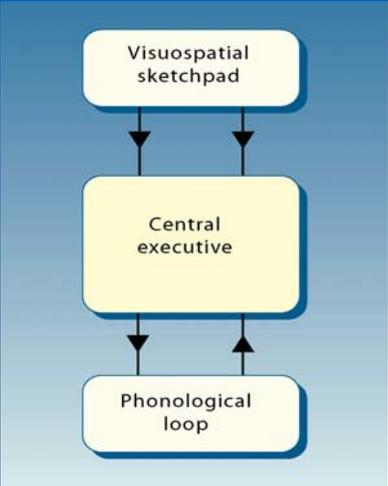
Fig. 12.12: Double dissociation on tests of item and source memory in healthy elderly adults who were rated as having “high” or “low” function on tests of frontal and temporal lobe function.



Component Analysis of Prefrontal Cortex

Content-Based Accounts of functional Specialization within Lateral Prefrontal Function

- Baddeley's model of working memory
 - ◆ Visual : Verbal => 'Central Executive'
- A different hypothesis (cf. Fig. 12.14)
 - ◆ Spatial : Verbal = Right : Left
 - ◆ Spatial : Non-Spatial = Right : Left



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graph TD; A[Visuospatial sketchpad] --> B[Central executive]; B --> A; B --> C[Phonological loop]; C --> B;
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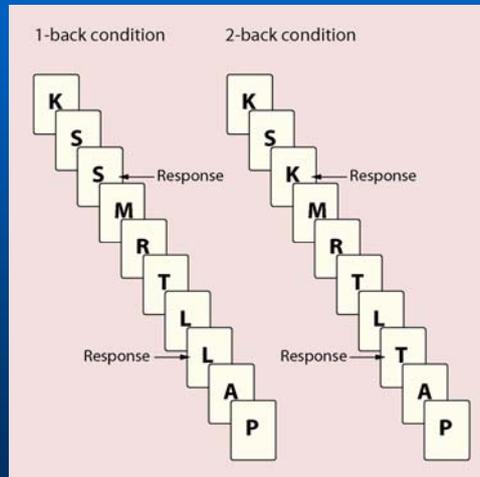
Fig. 12.13: Baddeley's model of working memory.

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Process-Based Accounts of functional Specialization within Lateral Prefrontal Function

- Different regions as a function for a particular task
- n -back tasks – require both the maintenance and the manipulation of information in working memory

Fig. 12.15: In n -back tasks, responses are required only when a stimulus matches one shown n trials before.

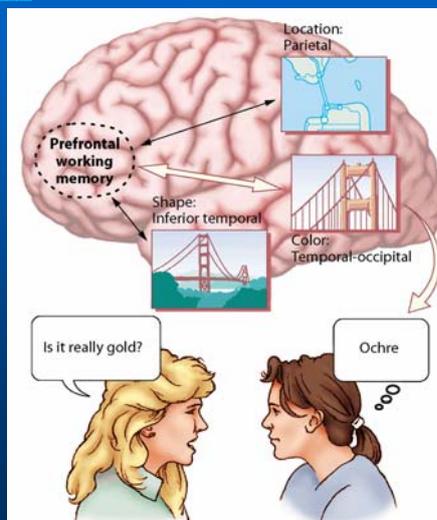


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The Selection of Task-Relevant Information - Brain areas involved in the selection of task-related information

- Selection of task-relevant information
 - from memory role to attention allocation role
- Inhibitory mechanism
- Dynamic filtering – requires an attentional component

Fig. 12.16: Prefrontal cortex not only provides a working memory buffer but also may use an inhibitory mechanism to highlight the information that is most relevant to the current task demands.



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The Selection of Task-Relevant Information – Filtering as an Inhibitory Process

- Dynamic filtering enhances attention and selection
- Filtering deficits is caused by the failure to inhibit irrelevant information.
- Poor performance in memory tasks also results from the failure of inhibition due to slower decay process.
- Failure of inhibition causes the dissociation between recognition and recency memory.
- High susceptibility to distraction in patients with lateral prefrontal lesions

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Goal-Oriented Behavior

Planning and Selecting an Action

- Our actions are not aimless.
- We act because we want to accomplish our goals and to gratify personal needs.
- Patients with damage to the prefrontal lobe are unable to sustain a plan of action and meet their goals.

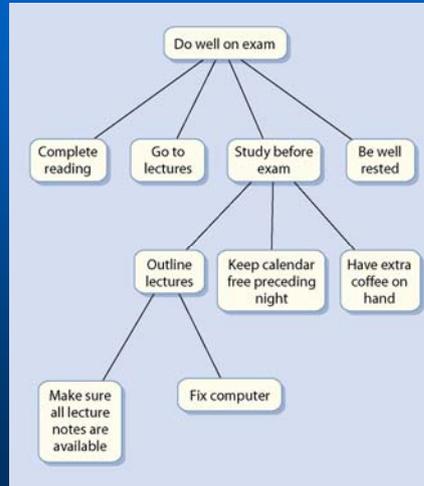


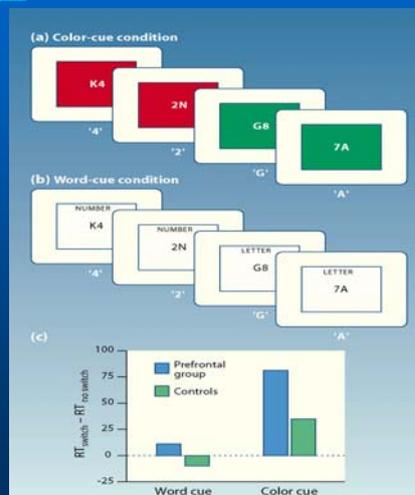
Fig. 12.21: An action hierarchy.

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Planning and Selecting an Action – Executive Control of Goal-Oriented Behavior (1/4)

- ‘Task Control’ – Monitoring and evaluating the different subgoals
- Shift our focus from one subgoal to another
- Patients with prefrontal lesions showed impairment only on the color cue condition.

Fig. 12.22: Task-switching experiment, with the task cued by either (a) a color or (b) a word. (c) Switching cost, the time required to switch from one task to the other.



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Planning and Selecting an Action – Executive Control of Goal-Oriented Behavior (2/4)

- Task switching – the most prominent foci were in the inferior frontal sulci in both hemispheres
- Not simply inhibiting – dynamic filtering between new courses of action

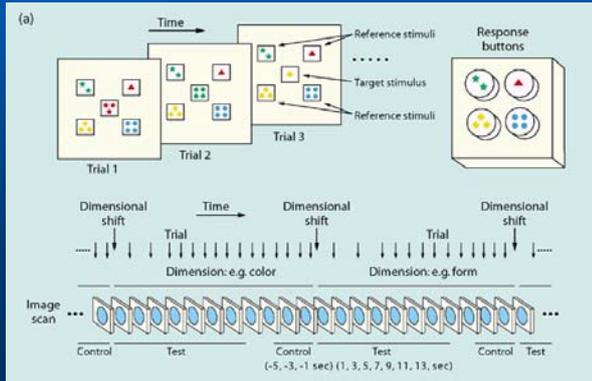


Fig. 12.23 (a): Modified Wisconsin Card Sorting Task for event-related fMRI. Stimulus displays and response board.

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Planning and Selecting an Action – Executive Control of Goal-Oriented Behavior (3/4)

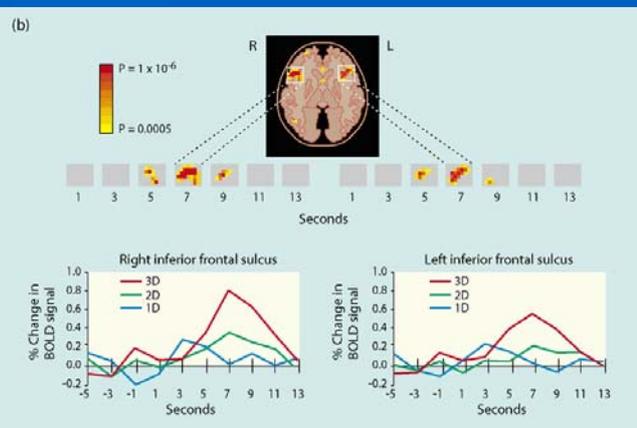


Fig. 12.23 (b): Increased activation was observed bilaterally in the inferior frontal cortex following the signal to shift dimensions.

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Planning and Selecting an Action – Executive Control of Goal-Oriented Behavior (4/4)

- Psychological model of executive control
- Supervisory attentional system (SAS) – favoring certain schema control

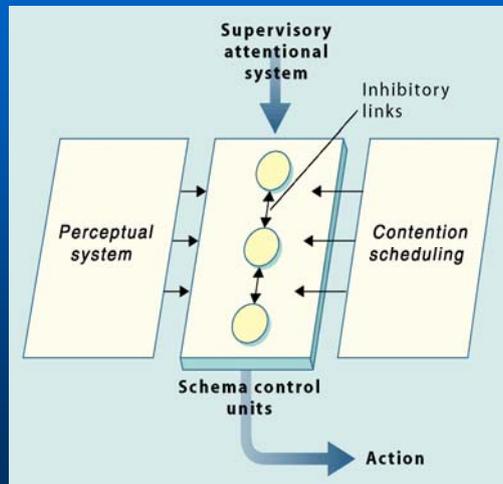


Fig. 12.24: Norman and Shallice's model of response selection.

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The Anterior Cingulate as a Monitoring System

- Coordinating activity across attentional system –executive attention
- Enable other regions to be most efficient given the current task demands
- With the prefrontal: selecting working memory buffers
- With the posterior: amplifying activity in one perceptual module over others

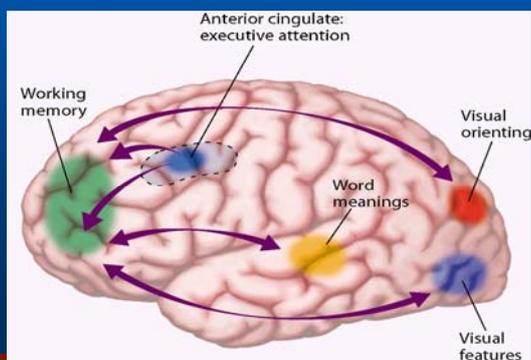


Fig. 12.25: The anterior cingulate has been hypothesized to operate as an executive attention system.

Summary

- Prefrontal cortex plays the crucial role in complex behavior and goal-oriented behavior.
- Lateral prefrontal cortex is conceptualized as a working memory system.
- The anterior cingulate is hypothesized to work in tandem with prefrontal cortex, monitoring the operation of this system.
- The prefrontal cortex can be a reservoir of the current contents of processing by linking up to stored representations in the cortex's more posterior regions – representations that help to select actions.

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Key Terms

anterior cingulate	recency memory
content-based hypotheses	response conflict
delayed-response task	selection of task-relevant information
dynamic filtering	source memory
error-related negativity	stimulus driven
executive functions	supervisory attentional system
goal-oriented behavior	task switching
inhibitory control	Wisconsin Card Sorting Task
lateral prefrontal cortex	working memory
monitoring	
perseveration	

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Thought Questions

1. What memory functions are associated with prefrontal cortex? How do these mnemonic functions differ from other types of memory?
2. Compared to the visual cortex, it has been difficult to identify subregions of the prefrontal cortex. What are some of the current hypotheses concerning functional specialization within the prefrontal cortex? Does the lack of specificity reflect the current lack of knowledge or some difference between anterior and posterior cortex? Explain your answer.
3. One of the cardinal features of human cognition is that we exhibit great flexibility in our behavior. Flexibility implies choice, and choice entails competition between alternatives. Describe some of the neural systems involved in response selection.
4. Review and contrast some of the ways in which the prefrontal cortex and the anterior cingulate are involved in monitoring and controlling processing.
5. The notion of a supervisory attentional system does not sit well with some researchers because it seems like a homuncular concept. Is such a system a necessary part of an executive system? Explain your answer.