Lecture 4
The frontal lobes

Essential Reading
- Gazzaniga, Ivy and Mangun, Cognitive Neuroscience, Chapter 11 and 12.
- Bor, D., Duncan, J., Wiseman, R.J & Owen, A.M. Encoding strategies dissociate prefrontal activity from working memory demand, Neuron, 37: 361-367

Additional Reading
- Kolb and Whishaw, Fundamentals of Human Neuropsychology, Chapter 16

Size of the frontal lobes in different species

From Fuster, 1980

Frontal functions

Family of relatively related functions including:
- inhibition of inappropriate responses
- working memory
- organisation of temporal information
- action planning
- ability to take advantage of structured material
  - in list learning (Stuss et al., 1994)
  - in spatial working memory

Perseveration errors in frontal patients

Assessed with Wisconsin Card Sorting Task
- Cards can be classified according to different criteria
- Patient learns classification rule using tester feedback
- Rule changed without warning
- Inability to consider novel rules
- What is the cause of perseveration?
  - Deficit in trial and error strategies?
  - Tendency to focus on single criterion
  - Lack of inhibition of previously reinforced dimension?
  - Inability to switch rules?

Source amnesia
- Correct recollection
- Failure in identifying context
  - (space and/or time) & source (i.e. who mentioned the fact)
- Experimental demonstration of source amnesia in frontal patients (Shacter et al. 1984)
  - 2 experimenters tell in turn fictitious facts to frontal patients
  - Patients remember what was mentioned but not who mentioned it
Source amnesia
Experimental demonstration of dissociation between item memory and source memory in healthy humans (Glisky et al. 1995).
Participants divided in high & low scorers in frontal and temporal neuropsychological tests.

Item memory
- recognize content of heard sentences
- larger gap between high & low temporal scorers

Source memory
- recognize source (male or female voice) of heard sentences
- larger gap between high & low frontal scorers

Frontal memory functions in monkeys

Winconsin General Test Apparatus (WGTA) = tray with food wells covered with stimuli

Working Memory
- Delayed response tasks
  - one well baited
  - wells covered with identical stimuli
  - location of bait changed from trial to trial
  - impaired by prefrontal damage

Associative memory
- wells covered with different stimuli
  - one stimulus constantly associated with reward
  - unimpaired by prefrontal damage

Recency discrimination task in humans
(Milner, Corsi & Leonard, 1991)
Presentation of sequences of paired pictures of objects
Participants periodically required to identify most recently presented member of pair
- one object in pair not previously presented at all (recognition)
  - frontal patients discriminate correctly
- both objects previously presented but in different trials (relative recency)
  - frontal patients fail

Frontal memory functions in monkeys

Recognition
- trial one = 3 objects & subject freely selects one
- trial two = 2 objects according to following conditions:
  - working memory
    - object just selected and one of previously presented objects
    - response shift impaired by prefrontal damage
  - recognition
    - object just selected and one novel object
    - selection of novel object unimpaired by prefrontal damage

Overall prefrontal areas involved in recency judgements

Functional specialisation of the prefrontal cortex

Content based approaches
- centred on spatial/non-spatial dichotomy derived from:
  - working memory (WM) model (e.g. Baddeley & Hitch, 1974)
  - dorsal/ventral visual systems (e.g. Ungerleider & Mishkin, 1982)
  - hemispheric specialisation

Process based approaches
- centred on type of task:
  - WM maintenance only
    - WM maintenance + processing (e.g. N-back)
  - WM + integration of information (could also explain source amnesia?)

Functional specialisation of the prefrontal cortex

Meta analysis of fMRI Studies (D’Esposito et al., 1998)

Dorsal PFC
- Spatial
- WM/ Processing Integration

Ventral PFC
- Verbal/Non-spatial
- WM only

Left PFC
- Non-spatial

Right PFC
- Spatial
Selection of task-relevant information
Role of prefrontal cortex in allocation of attentional resources

Dynamic Filtering (Shimamura, 2000)
- working memory as portions of activated LTM needed for specific task
- attentional component needed to filter out irrelevant information
- could explain source amnesia as context may require more attentional resources than content?
- could explain enhanced Stroop effect in frontal patients (no WM demand but need for Dynamic Filtering?)

Dynamic filtering & Semantic Generation Task (Thompson et al., 1997; 1998)
-Participants given a noun and asked to generate a verb associated with it
-Low selection condition
-Presentation of nouns associated with fewer verbs
-High selection condition
-Presentation of nouns associated with more verbs
- More activation of inferior left frontal cortex (b)
- Patients with inferior frontal lesions (c) unable to generate verb associates or particularly slow in doing so

Filtering as inhibition of inappropriate responses
Electrophysiological studies E.g. (Knight & Gaabowecy 1995)
Evoked potentials for attended and non-attended stimuli have different amplitude in healthy participants
The difference is reduced in frontal patients due to lack of inhibition.

Could deficits in inhibition mechanisms explain deficits in recency judgements?
Recency judgments may be based on residual activation of memory trace of items
Lack of inhibition could delay the decay process and confuse decisions based on comparison of relative activation of items

Executive control of goal directed behaviour
Components of action plan (Duncan 1995)
- identify goal and set subgoals
- identify consequences of goals and subgoals
- assess requirements of goals and subgoals

Task control
- shift out attention from one subgoal to another

Frontal patients impaired in naturalistic tasks requiring planning but not memory
- carry out a number of errands from list (Shallice & Burgess, 1991)
- plan family budget (Goel et al., 1997)

Task-switching experiments
- Task 1: name letter
- Task 2: name digit
- Type of task cued by either words or colour
- Task goal is switched every 2 trials
- Cost of task switching derived from subtracting RT from trials requiring task switch and RT from trials not requiring task switch
- Frontal patients not impaired in task switching when word tells them to do so rather than having to remember rule from memory
The encoding of structure in Working Memory
Semantic grouping of word lists (Stuss et al. 1994)
  16 words belonging to 4 semantic categories
  lists segregated by semantic categories and lists not segregated
  by semantic categories
  difference between frontal patients and controls only emerged
  for lists segregated by semantic categories

Organisation of digit lists (Bohr et al., 2004)
  mathematically structured lists
  mathematically unstructured lists
  selective activation of Lateral prefrontal Cortex during encoding
  of mathematically structured lists

Frontal functions and the organisation of memory material
Chunking in spatial working memory (Bor et al., 2003)
  fMRI study
  Modified spatial span task
  Structured (a) /unstructured (b)

Selective activation of lateral frontal cortex
  during encoding of structured sequences

Summary
Frontal lobes
  • particularly expanded in humans
  • frontal damage causes family of relatively related deficits
  • frontal functions and working memory
  • frontal functions and selection of task relevant information
  • frontal functions and task control
  • frontal functions and the organisation of memory material