Prefrontal cortex

- **Function of prefrontal cortex** (Goldman-Rakic, 1992). "The cardinal function of prefrontal cortex is the regulation of behaviour by internalized (symbolic) cues. Fundamental to this capacity is the ability of an organism to access and hold information in mind and then to use that information to guide responses in the absence of external cues" – **working memory**.
- (Buckner & Peterson, 1996). Areas in the PFC are active during tasks requiring retrieval from LTM.
    - *Left inferior PFC involved in semantic memory retrieval.* This region might be used to access and maintain a representation of words during their retrieval. There is no activation in simple speech tasks. Areas in the more anterior region of left PFC (46, 47, 10) are activated during tasks requiring access to word meaning. There is a priming effect (reduced activity the second time).
    - *Left inferior PFC involved in other kinds of memory*. Verbal working memory; tasks known to encourage storage of verbal material into episodic memory…
    - *Right anterior PFC involved in episodic memory retrieval.* This is very consistent. In addition, posterior prefrontal areas are activated, sometimes bilaterally; the pattern of posterior activations may be related to the kind of episodic information being retrieved. Verbal retrieval: posterior left frontal area (in addition to right anterior PFC); face (pictorial) retrieval: right prefrontal areas only. Paired associate recall of picture names (picture & verbal): posterior PFC within the frontal operculum, bilaterally. The common area of right anterior PFC may guide processes in other areas…
- (Petrides, 1996). Area map of frontal cortex (p58).
    - The mid-dorsolateral frontal cortex appears to be specialized for holding information on-line for monitoring and manipulating stimuli. (A system for recoding events in posterior association cortex in terms of planned action or the monitoring of expected acts/events?) A system for the on-line maintenance and monitoring of cognitive representations of intended acts and the occurrence of events from a given set.
    - Direct and indirect connections with the limbic region of the medial temporal lobe, via cingulate and orbitofrontal cortex.
    - *Two-level hypothesis:* **mid-ventrolateral** FC (45, 47/12) consitutes a first level of executive interaction with information held in posterior cortical association areas. It is critical for the active (i.e. strategic) encoding and retrieval of specific information held in posterior cortical regions and thus in selecting, comparing or decigin on information held in STM and LTM. The **mid-dorsolateral** FC (9 & 46)) constitutes a second level of interaction and is involved when several pieces of information in working memory need to be monitored and manipulated on the basis of the requirements of the task or the subjects' current plans.
    - In the monkey, lesions of the mid-dorsal part of lateral frontal cortex (dorsal part of 46, and 9) result in severe impairments on nonspatial working memory tasks.
    - Lesions of posterior dorsolateral frontal cortex (8 and rostral 6) impair conditional associative learning but not self-ordered tasks.
    - (Simple mnemonic judgements based on relative recency/primacy of stimuli need not be affected by dorsolateral frontal damage.)
    - The problems of mid-DLFC lesions stem from the monitoring requirement of the task: the number of stimuli that must be considered as responses are made.
- Dopamine loss (or perhaps dopamine and noradrenaline loss) in the principal sulcus impairs working memory (delayed response task) but not associative memory (visual pattern discrimination). [Intracerebral 6-OHDA or chronic MPTP.] **D_1 receptors** are crucial for this function. There is a **dissociation of behaviour controlled by sensory cues and memory cues**; monkeys with prefrontal lesions are not impaired when behaviour is elicited by learned cues present at the time of response. PD patients show similar impairments.

Functions of dorsolateral PFC

- human lesions lead to… perseveration (WCST), distractibility, disinhibition, diminished planning/initiative, recency memory, temporal ordering in long-term recall, verbal fluency/recall, self-ordered working memory tasks, certain types of associative learning, ?impaired egocentric spatial processes, "utilization" behaviour, lack of hygiene, release of primitive reflexes. WAIS IQ largely unaffected. Hemispheric differences not well-defined. "Apparently opposed signs (perseveration/distractibility) are quite common."
- **sulcus principalis** required for delayed-response (DR) tasks. Lesions cause a deficit even at very short delays (hippocampal lesions only apparent at longer delays). [In humans, frontal patients are only rarely impaired on the conventional DR task; perhaps they use verbal strategies.] Spatial working memory. D_1 receptors modulate spatial working memory here (and some evidence of NA involvement). Infants' A-not-B error can be likened to a DR task; infants have an immature PFC below 12 months. [DR task: food placed on the two sides in random sequence, screen goes down, delay, screen goes up and monkey can respond. A-not-B task: locations baited until correct response occurs twice in a row, then location switched to other side.] Infants and monkeys both perseverate (unlike hippocampal monkeys when they fail the task). Is the function of the frontal lobes to resist habitual tendencies; intentionality? DL-PFC implicated in Wisconsin Card Sorting Test – and this is not easily attributable to working memory function alone.

Functions of orbitofrontal PFC

- Concerned with stimulus-reward learning. Single units fire on the first trial of a reversal. Part of a network (temporal cortex, amygdala, ventral striatum, MD thalamus) concerned with S–R relationships? For both object reversal and spatial reversal, lesions caused animals to perseverate (Jones & Mishkin); once they had got rid of this tendency, they could learn the new S–R association. In contrast, amygdala lesioned monkeys had more problems at this stage.
- See *Descartes' Error*, below.

Descartes' Error:

- **Ventromedial prefrontal cortex:** damage impairs reasoning/decision making and emotion/feeling, especially in the personal/social domain. (Reason and emotion "intersect" here, and in the amygdala.)
- **Right somatosensory cortex:** damage causes anosognosia – compromised reasoning/decision making, emotion/feeling and basic body signalling. (Hemispheric specialisation probably in order to have *one* final controller. Two would be a problem.) **Right insula and parietal lobe** in particular (anterior insula = visceral sense). Explanations p.154. The neural self and the basis of subjectivity, p.236–243 (very interesting).
- Prefrontal cortex beyond VM sector (i.e. **dorsolateral PFC**): damage compromises reasoning/decision making, but in a different pattern: either there is a widespread intellectual deficit, or the defect is in words/numbers/objects/space (not personal/social).
- **Anterior cingulate cortex:** damage impairs volition (p.71) – the source of the energy for external and internal action.
- Serotonin in PFC promotes social behaviour and reduces aggression (p.76)
- Dispositional representations, convergence zones (ch.5)
- Amygdala and limbic system involved in processing *primary emotion*; frontal cortex involved with *secondary emotion*.
- There is some RHS bias to emotional processing.
- The entire frontal region is interconnected (p.?).
- Emotion-related movement is controlled from anterior cingulate region, from other limbic cortex (in medial temporal lobe) and from the basal ganglia (p.140), as opposed to motor cortex. There is little volitional control of the emotional route.
- Feelings (basic, subtle, *background*), p.143 on.
- The somatic marker hypothesis (p.173). The somatosensory cortex is either affected directly by the body state, or by PFC and amygdala (the "as if" route). Somatic markers may operate consciously or covertly – intuition (p.187). They also boost attention. This is also the basis for ordering (behaviour, consciousness): competing alternatives are ranked, and then behaviour/consciousness runs through them. Working memory is required to support the ranked images (p.199). The Gambling Game and interpretations of PFC dysfunction (chapter 8, esp. pp.218–219).
- Prefrontal cortex categorises things with regard to personal relevance (p.182).
- Dorsolateral and upper medial PFC can activate premotor cortices (and from their, M1/M2/M3). PFC can also activate subcortical motor structures (basal ganglia). Ventromedial PFC can affect autonomic NS and hypothalamus.