Basic principles of attention and sensory decision-making, from sensory cortices to frontal areas
Organization and representation of goal-directed actions
Selection of potential actions
The ‘ ’ (dorsal) pathway

• Do not mistake with the ‘ ’ (old) pathway: SC and pulvinar
• W represents potential targets to reach with respect to body, and is involved in (see Ramachandran, Balint’s syndrom)
The ‘ ‘ (dorsal) pathway

- Do not mistake with the ‘ ’ (old) pathway: SC and pulvinar
- **W** represents potential targets to reach with respect to body, and is involved in (see Ramachandran, Balint’s syndrome)
- Lateral Intraparietal cortex (**W**:)
  - est-order area in the visual hierarchy of the dorsal stream
The ‘ ’ (dorsal) pathway

• Do not mistake with the ‘ ’ (old) pathway: SC and pulvinar

• W represents potential targets to reach with respect to body, and is involved in (see Ramachandran, Balint’s syndrom)

• Lateral Intraparietal cortex (W):
  → highest-order area in the visual hierarchy of the dorsal stream
  → involved in gaze control, strongly connected with the frontal eye field ( ) and superior colliculus ( I )

• Both LIP and FEF stimulation elicit (shorter delay for FEF [<20ms¹], closer to motor output, than LIP [~40ms²])
Defining PFC

- (Pre)frontal cortex comprises all the areas reciprocally connected with the mediodorsal (MD) thalamic nucleus
- Abundant dopamine innervation (contrary to parietal cortex) → ADHD

Preuss, 1995
Dissociation of functional roles of OFC and lPFC

- 2AFC attentional task
- Lesion of area 9 (lateral) or OFC

Dias et al, 1996
Dissociation of functional roles of OFC and IPFC

- 2AFC attentional task
- Lesion of area 9 (lateral) or OFC
- Lateral PFC controls (Posner’s orienting attention)
- OFC deals with (valence)/updating rule

Dias et al, 1996
Divisions of PFC

- Medial and orbital frontal cx (‘sensor’ PFC):
  → internal signals (from reward to emotions)

- Lateral frontal cx (‘doer’ PFC):
  → external signals (executive [top-down] attention, decision-making and cognitive planning)
Divisions of PFC

- Medial and orbital frontal cx ('sensor' PFC):
  - signals (from reward to emotions)

- Lateral frontal cx ('doer' PFC):
  - signals (executive [top-down] attention, decision-making and cognitive planning)
  - largest growth in primates, and particularly humans (dotted region)

Preuss, 1995
Frontal cortex laminar organization

- With 5 layers, agranular cx is intermediary between neocx and allocx (hippocampus and piriform cx)

Zald, 2007
Defining PFC across species

Ventral (bottom) views
orbital PFC

Side view
Defining PFC across species

- Is mouse frontal cortex a replica-in-miniature of primate’s one?
- ? mouse mPFC ↔ primate dlPFC ?
Defining PFC across species

Passingham and Wise, 2012
Defining PFC across species

- Is mouse frontal cortex a replica-in-miniature of primate’s one?
- ? mouse mPFC ↔ primate dlPFC?
  → MD reciprocal connections
  → widespread dopamine innervations

Wise, 2008
Defining PFC across species

- Is mouse frontal cortex a replica-in-miniature of primate’s one?
- ? mouse mPFC ⇔ primate dIPFC ?
  - cytoarchitecture do no suggest this view
  - not completely supported by behavioral results in spatial delayed-response task
  - still infra-, pre-limbic, agranular orbital and anterior cingulate are shared

Wise, 2008
# PFC nomenclature

<table>
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<tr>
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<td>Prearcuate (monkey)</td>
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<td>Caudal lateral (humans)</td>
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<td>46</td>
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<tr>
<td>Principal sulcus (monkey)</td>
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<td>Middle frontal gyrus (humans)</td>
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</table>
Selection of information and action in LIP

Snyder et al., 1997

Katsuki and Constantinidis, 2012
Selection of information and action in LIP

- RF are both sensory and motor-related
- Tasks demanding attention make difficult to disentangle attention and motor action

Gottlieb and Balan, 2010
Selection of information and action in LIP

- RF are both sensory and motor-related
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Selection of information and action in LIP

- In a conflict situation, LIP neurons

→ Selected action can be contradicted or complemented in downstream areas
Selection of information and action in LIP

- In a conflict situation, LIP neurons

→ Selected action can be contradicted or complemented in downstream areas

- Only a few neurons coded gaze direction unambiguously

Gottlieb and Goldberg, 1999
Selection of information and action in LIP

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8-direction gaze task

Gottlieb and Balan, 2010
Selection of information and action in LIP

- RF are both sensory and motor-related.
- Tasks demanding attention make difficult to disentangle attention and motor action.

Gold and Shadlen, 2007
Selection of information and action in LIP

• RF are both sensory and motor-related
• Tasks demanding overt attention make difficult to disentangle attention and motor action
• Firing rate correlates with

→ LIP represents a final stage for the , dynamically incorporating information (even at 0%!)

Gottlieb and Balan, 2010
Decision-related parietal activity in EEG

- EEG reflects a similar than LIP neuronal pools

Kelly and O’Connell, 2013
Intracortical manipulation of accumulated information

Intracortical MT or LIP stimulation during motion presentation

Hanks and Shadlen, 2006
Gold and Shadlen, 2007
Intracortical manipulation of accumulated information

- Intracortical MT or LIP stimulation during motion presentation
- MT stimulation have much bigger effect

Hanks and Shadlen, 2006
Intracortical manipulation of accumulated information

- Intracortical MT or LIP stimulation during motion presentation
- MT stimulation have much bigger effect, in accordance to

Gold and Shadlen, 2007
PFC and decision-making

- Recordings in areas 8 (FEF) and 46

Kim and Shadlen, 1999
PFC and decision-making

- Recordings in areas 8 (FEF) and 46
- Similar picture than in LIP
- Competition between different pools of neurons

Kim and Shadlen, 1999
PFC and decision-making

- Recordings in areas 8 (FEF) and 46
- Similar picture than in LIP
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- Confirms (LIP-like)

Kim and Shadlen, 1999
PFC and decision-making

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- Dependence of outcomes confirms accumulation of sensory evidence (LIP-like)

Kim and Shadlen, 1999
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Kim and Shadlen, 1999
Parietal and frontal cortices
Behavioral Paradigm

Parallel Auditory and Visual Tasks - Conditioned Avoidance

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<tr>
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Time (in intervals)

TORC (Ref) ~ Interrupted TORC

Tone (Ref) ~ Tone-in-TORC

Steady Light

Clicks (Ref) ~ Clicks (Target)

Flashing Light
Rapid Plasticity in A1

Ferret in Experimental Set-up

Quantifying Spectral Plasticity (i.e. Change in STRF shape)
Tone

Aversive

Systematic change at the target frequency across the A1 population

Fritz et al., 2003. Nature Neuroscience
dIPFC and adaptive behavioral gating
dIPFC and adaptive behavioral gating

Fritz et al., 2010
dIPFC and adaptive behavioral gating

Top-down control

• Behavior-dependent task-relevant response in dIPFC
• A1-FC LFP coherence reflects cross-area communication

Fritz et al, 2010
dIPFC and adaptive behavioral gating

Top-down control

- • I W

Fritz et al, 2010
Control of attention through the brain network

Saliency map refers to the combination of bottom-up and top-down attentional effects to select salient stimuli.
dPFC and PPC: who is doing what?
Take-home messages

• Both parietal and frontal cortices contain a mixture of sensory/cognitive/motor variables
• PFC can specifically gate its response to attended stimuli
• PFC integrates the ventral and dorsal stream (+ amygdala, hippocampus...), allowing even more flexibility
dPFC and PPC: who is doing what?
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• Both parietal and frontal cortices contain a mixture of sensory/cognitive/motor variables
• PFC can specifically gate its response to attended stimuli
• PFC integrates the ventral and dorsal stream (+ amygdala, hippocampus...), allowing even more flexibility

→ rejection...???