Temporally Sustained Activity in Lateral Prefrontal Cortex Supports Decision Making

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A decision is...

... a deliberate process that results in explicit intention to pursue/avoid course of action.
Decision-making is a core cognitive function
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1. Interpreting sensory information

2. Weighing alternative choices

3. Selecting an action
PFC critical for decision-making

Humans

Primates

Area 1/3b
Area 2
Area 5
S2
VPC
DPC
MPC
M1

Badre et al, 2010; Romo & De Lafuente, 2013
Aims

1. Examine how and when PFC engages in decision-making

2. Identify cortical distribution of decision-making networks

3. Determine how specific features of local cortical activation are related to behavior
Electrocorticography
Word Repetition

- Categorization - Visual
- Face Gender Discrimination
- Face Emotion Discrimination
- Word Repetition

- Categorization - Auditory
- Self Referential - Auditory
- Self Referential - Visual

- Antonym Generation

19 subjects
8 tasks
Total coverage – 1804 electrodes recorded
Broadband high gamma indexes local cortical activity
Broadband high gamma indexes local cortical activity

![Graph showing broadband high gamma activity over time and frequency with z-score colorscale](image)
Total coverage – 1804 electrodes recorded
Active Electrodes – 53% of all electrodes
Consistent temporal patterns of HG activation

1 Subject, Task: Antonym Generation
Consistent temporal patterns of HG activation

All left hemisphere subjects
Consistent temporal patterns of HG activation

Fig. 29.—Motor cortex. Each black dot represents an actual motor response. The number 4 indicates where Area 4 extends from the anterior wall of the fissure on to the surface, according to Vogt. The remainder of the outer surface of the precentral gyrus is made up of Area 6a alpha. O = conjugate movements of eyes to the opposite side or upward.

Penfield & Boldrey, 1937; Penfield & Perot, 1963
Duration: sustained activation from stimulus through response

46 duration clusters
283 electrodes
33,000 trials
Active Electrodes
29% of active electrodes are duration
Left Hemisphere:
33% of active electrodes are duration

Left Frontal Cortex:
53% of active electrodes in left frontal cortex are duration
71% of active electrodes in left MFG are duration
Duration clusters peaks precede response cluster peaks

% change baseline HG

Time (ms)

Mean RT

Duration cluster
Response cluster

1 subject, Task: Self Referential - Visual
Features of the HG signal

DURATION CLUSTER

RTs
Features of the HG signal

DURATION CLUSTER

Trials

Time (ms)

RTs

HG onset
HG onset times correlate with RT

\[ r = 0.67 \]
\[ p < 0.001 \]

DURATION CLUSTERS
Across all tasks and subjects
HG onset times correlate with RT

**HG ONSET TIME**

Across all tasks and subjects

**DURATION CLUSTERS**

Across all tasks and subjects

**STIMULUS CLUSTERS**

Across all tasks and subjects

$r = 0.67$

$p < 0.001$

$r = 0.22$

NS
Features of the HG signal

DURATION CLUSTER

Trials

HG onset

Time (ms)

RTs
Increased HG peaks and latencies for longer RTs

2 x 2 ANOVAs p<.0001 for all;
For duration clusters: long > short, p<.001
Increased noise for longer RTs

2 x 2 ANOVAs p<.0001 for all; For duration clusters: long > short, p<.001
Role of noise in decision-making?

1. Stochastic Resonance
Stochastic Resonance

Activation Threshold
Signal + Noise

McDonnell & Abbott, 2009; Buzsaki, 2011
Stochastic resonance with increasing noise
BUT: Stochastic resonance predicts more noise for short RTs
BUT: Stochastic resonance predicts more noise for short RTs
Role of noise in decision-making?

1. Stochastic Resonance

1. Speed-Accuracy Tradeoff
   (increase in activation threshold)
Increasing activation threshold with increasing number of options

Opris & Bruce, 2005
Conclusions

• Cortical patterns of broadband HG correspond to distinct stages of cognitive processing.

• RTs depend on temporal engagement of duration clusters.

• The timing of decision execution depends on the peak of the broadband HG activity.

• The activation threshold for executing a decision increases throughout a trial, possibly driven by noise accumulation.
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