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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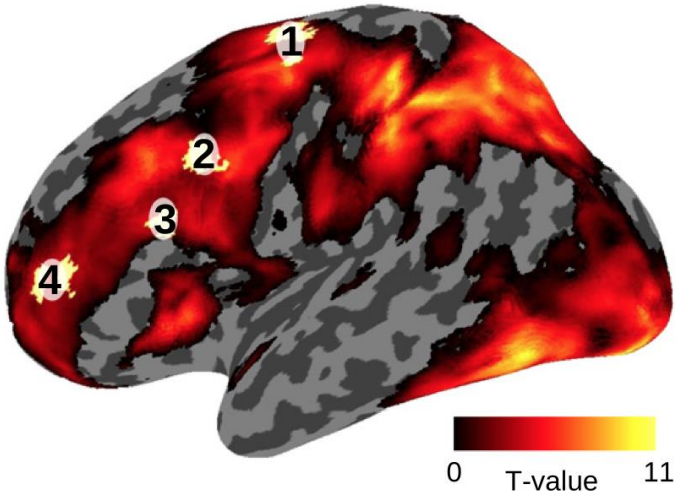
1. Interpreting sensory information
2. Weighing alternative choices
3. Selecting an action

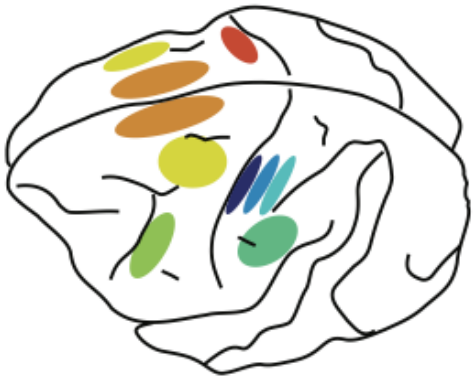
PFC critical for decision-making

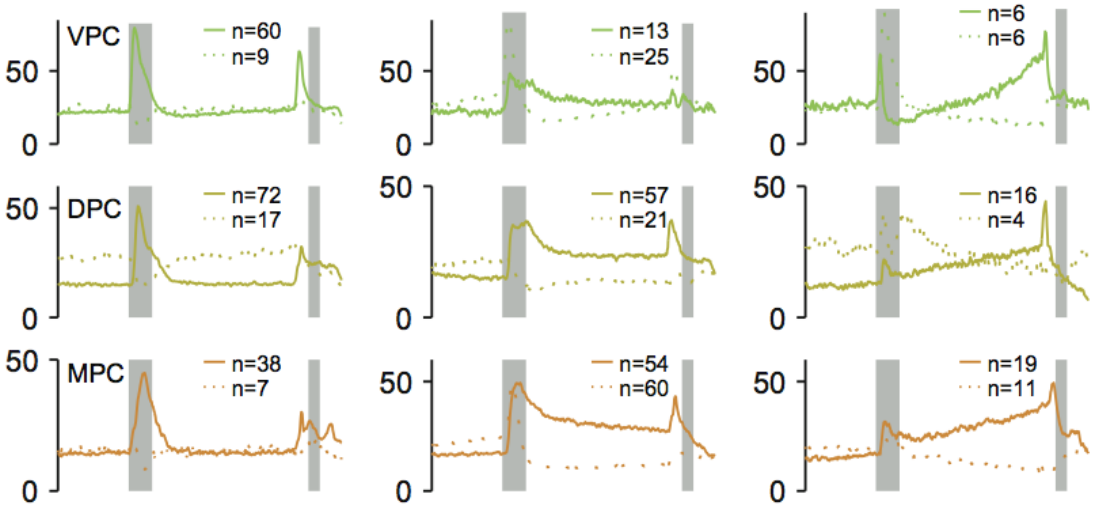
Humans



Primates

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





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

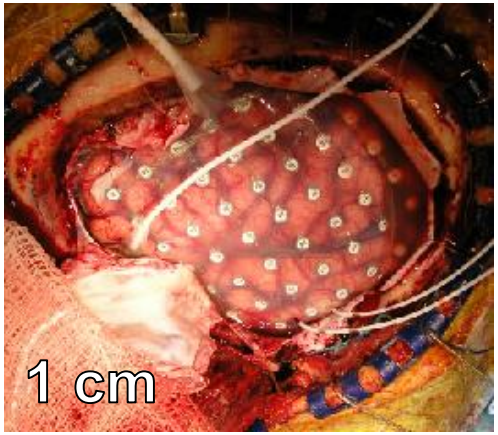
Aims

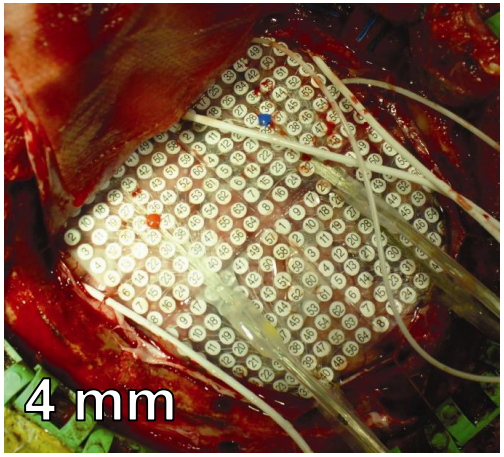
1. Examine how and when PFC engages in decision-making

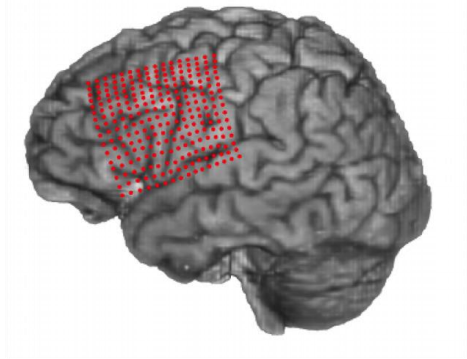
2. Identify cortical distribution of decision-making networks

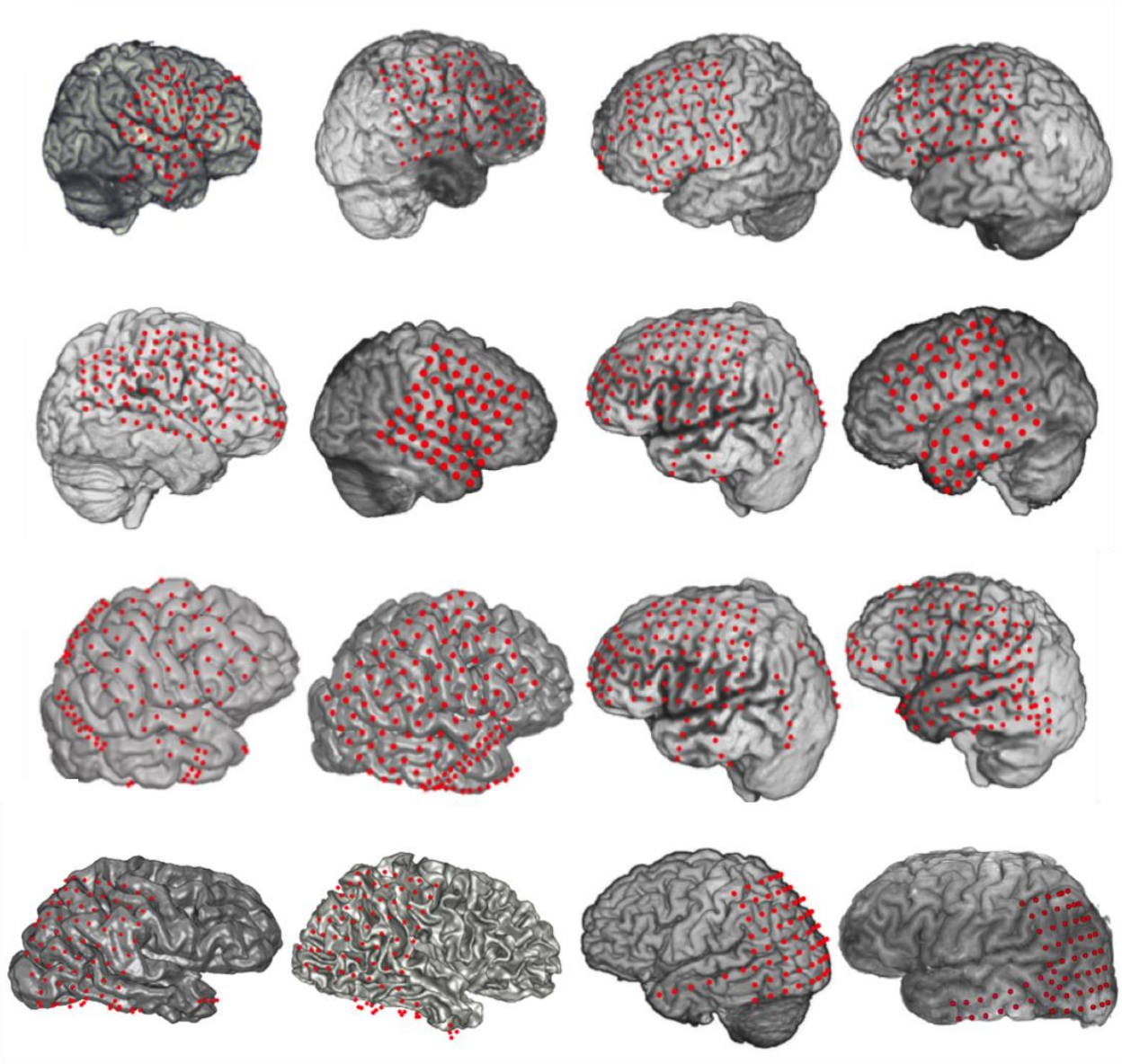
3. Determine how specific features of local cortical activation are related to behavior

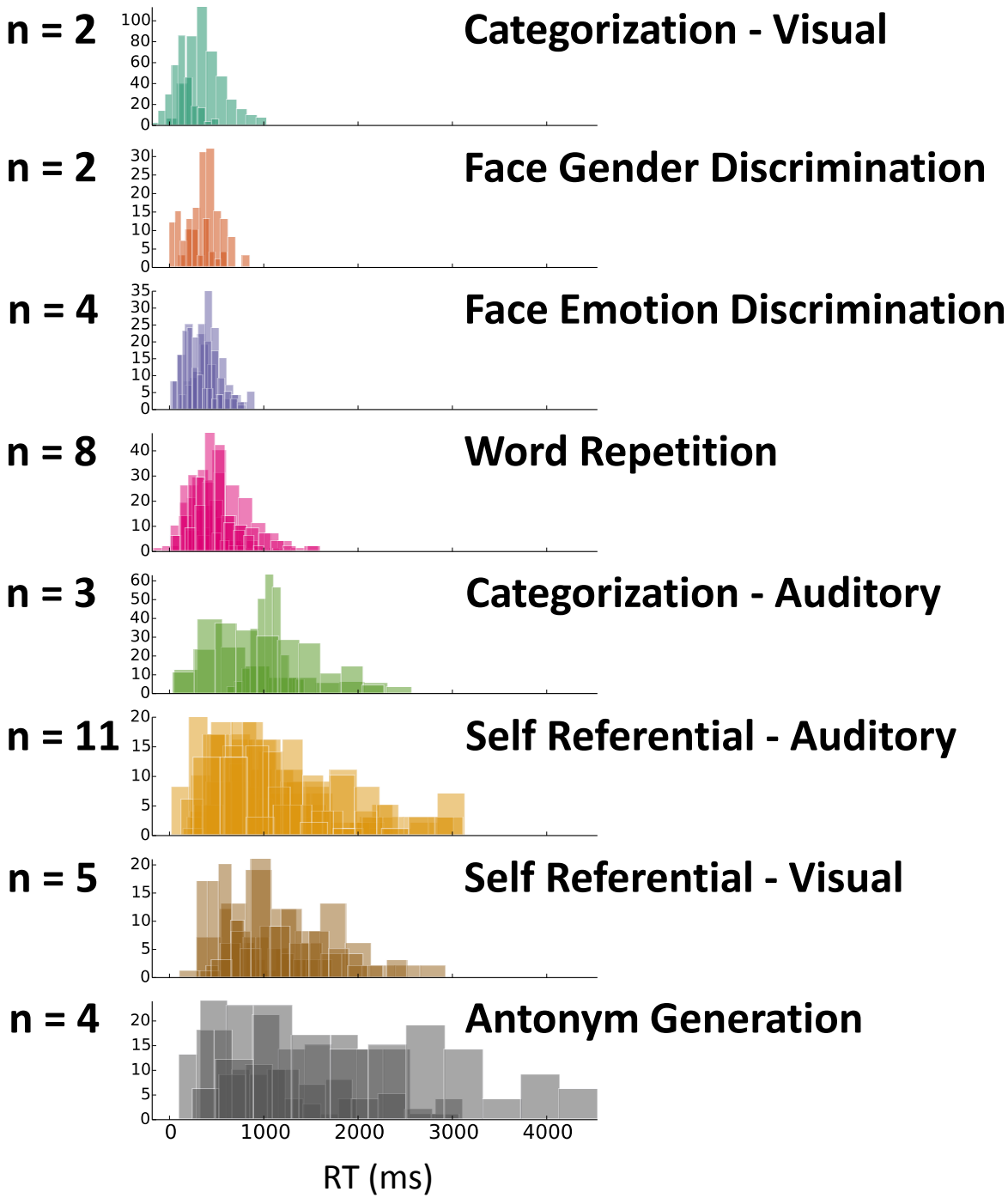
Electrocorticography





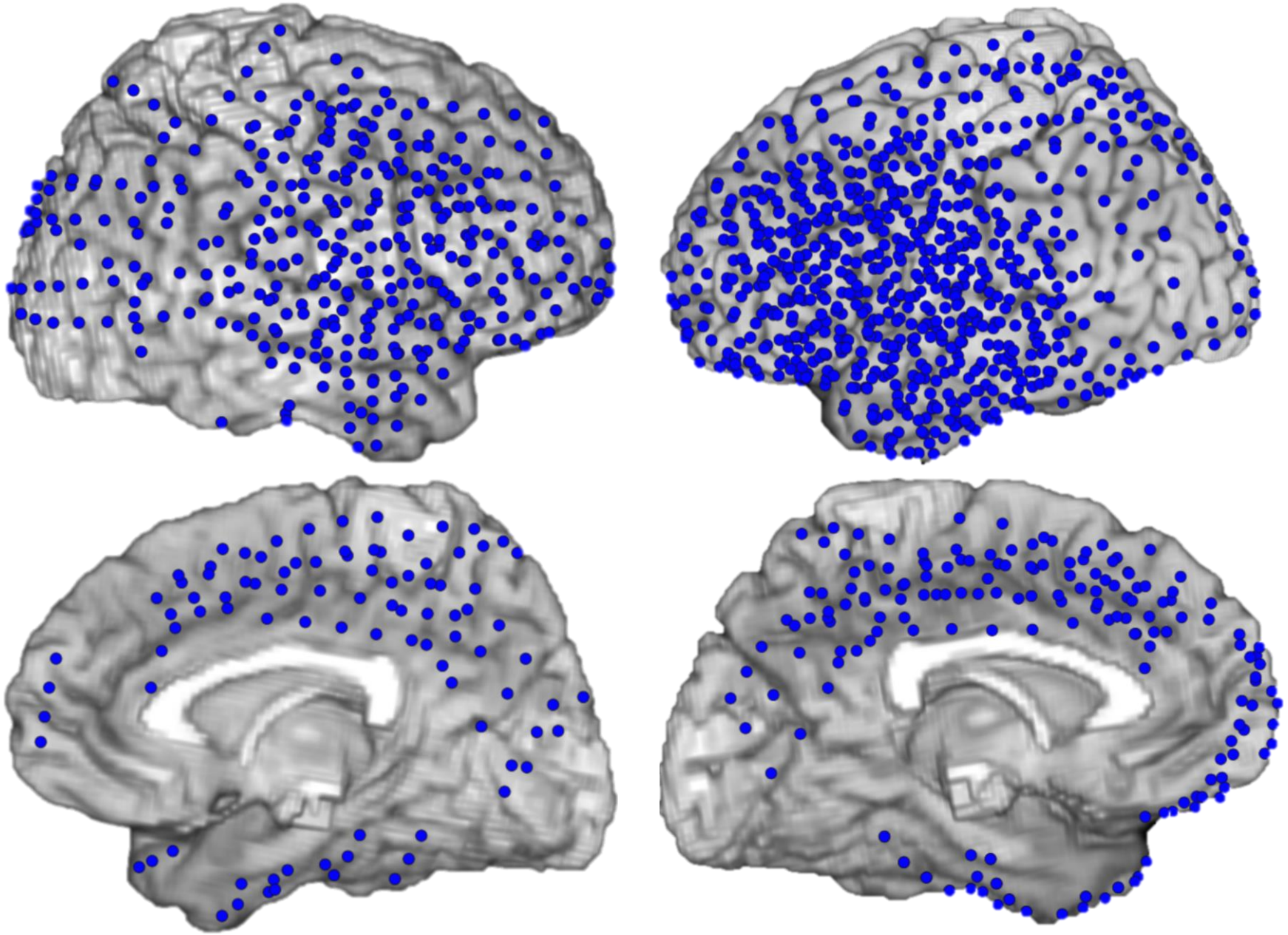




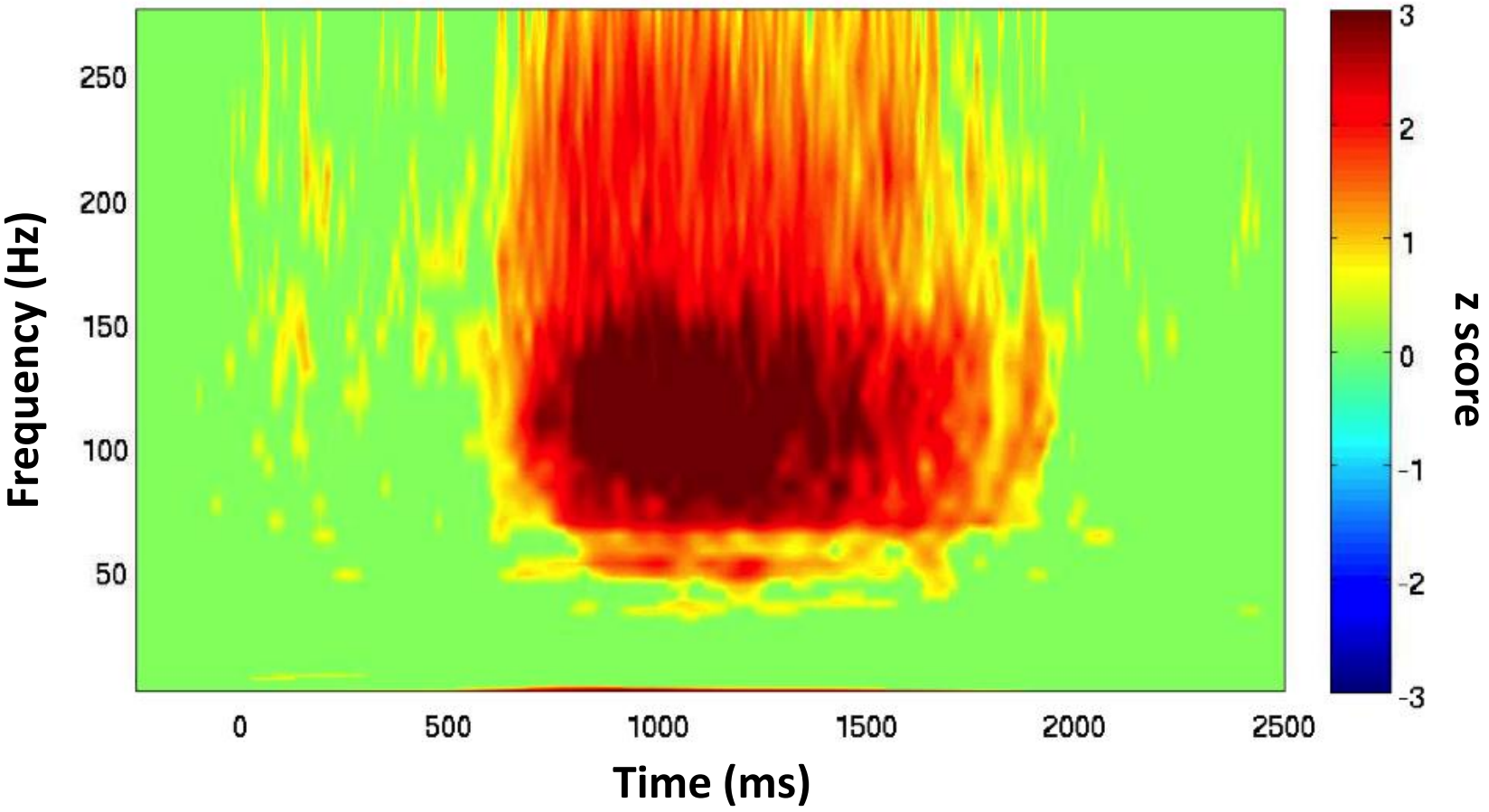


19 subjects
8 tasks

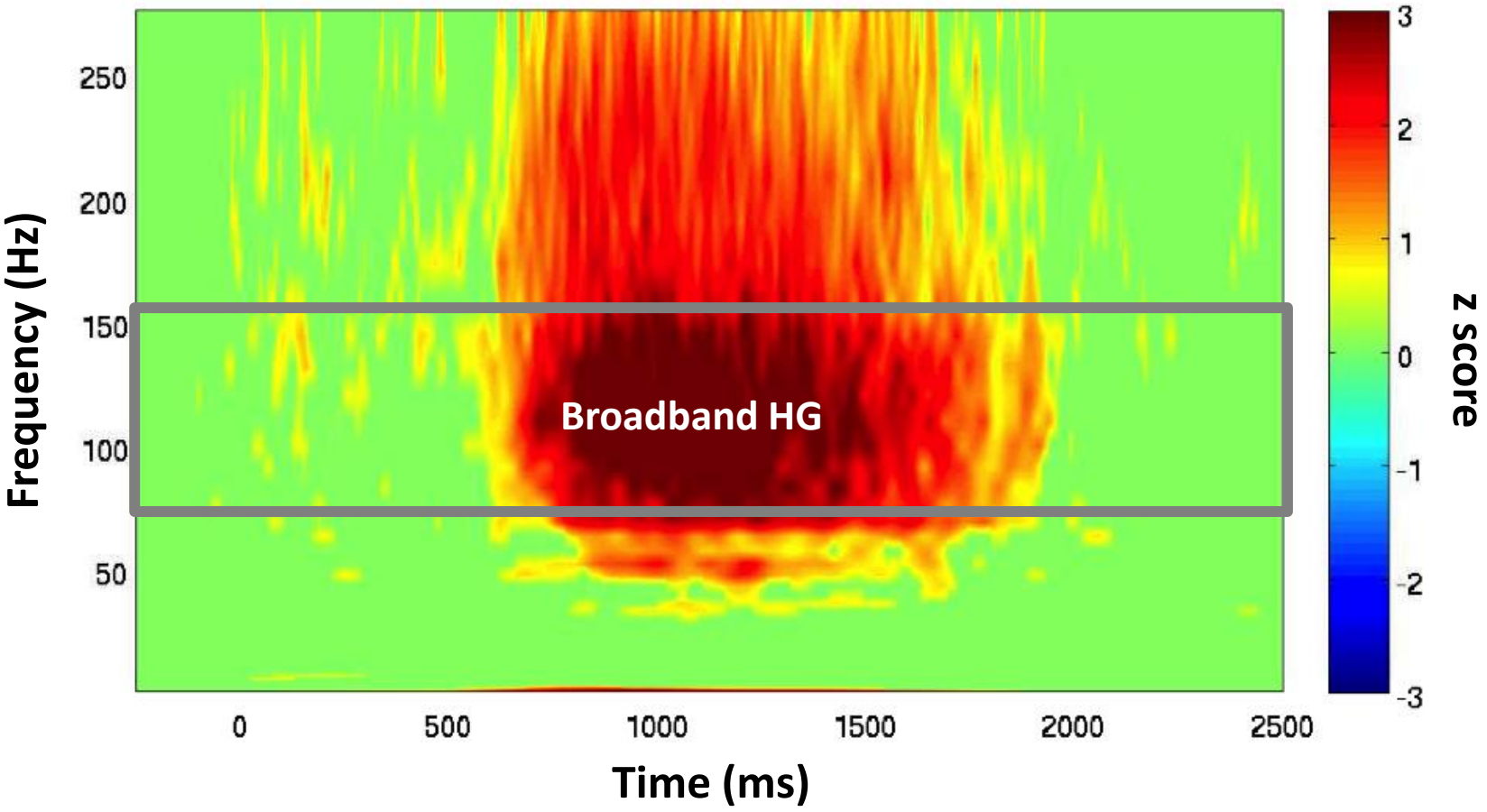
Total coverage – 1804 electrodes recorded



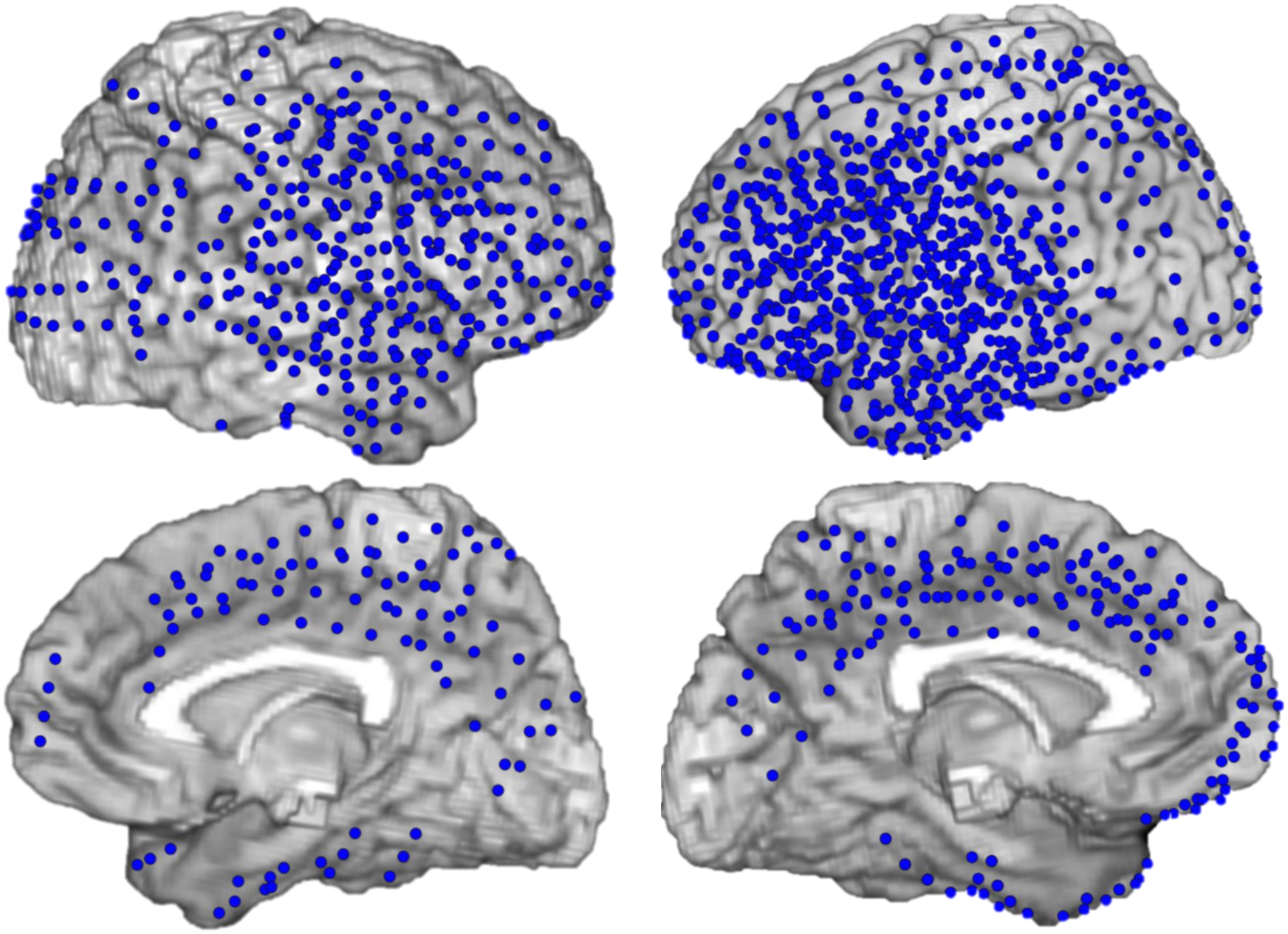
Broadband high gamma indexes local cortical activity



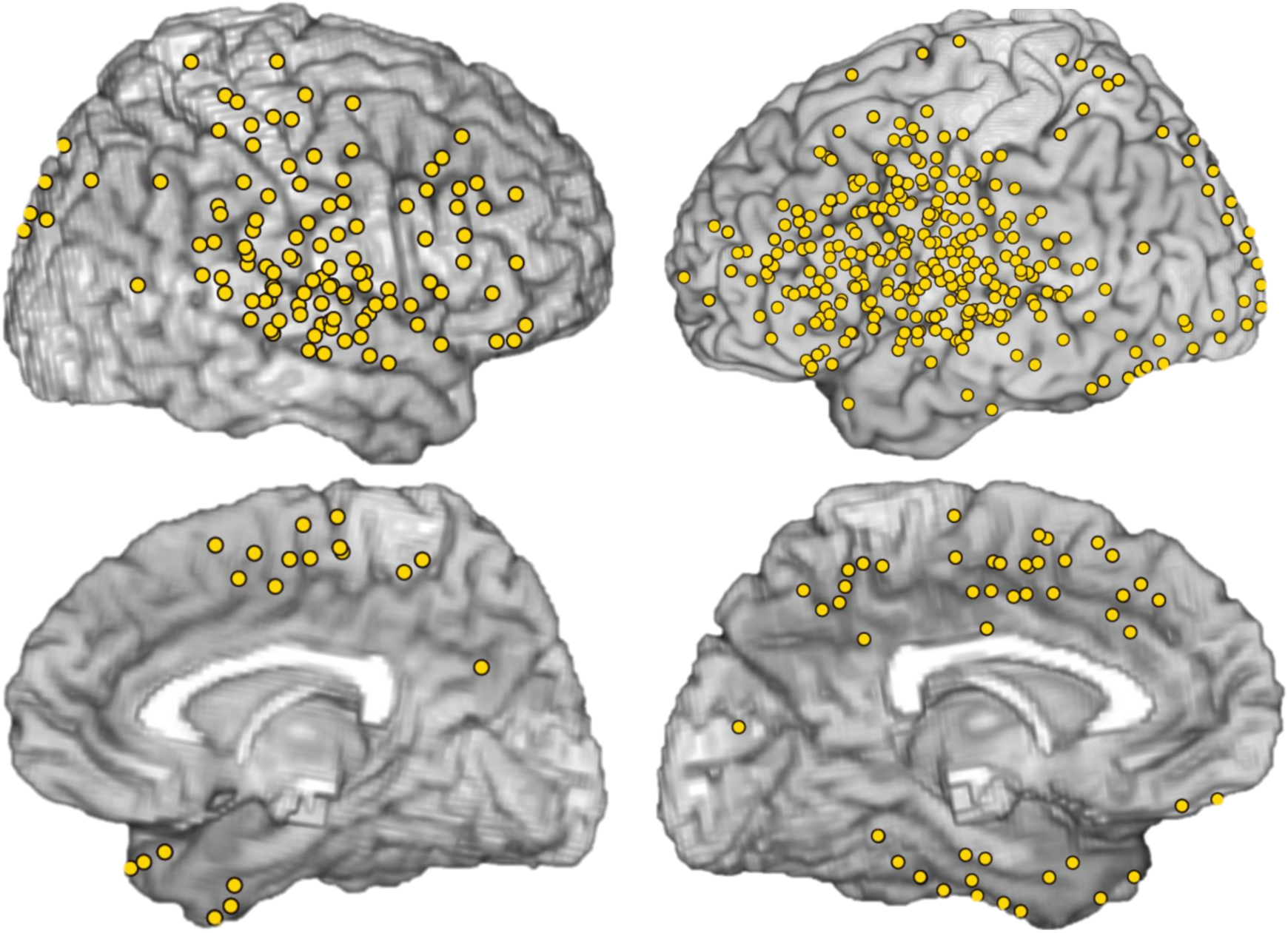
Broadband high gamma indexes local cortical activity



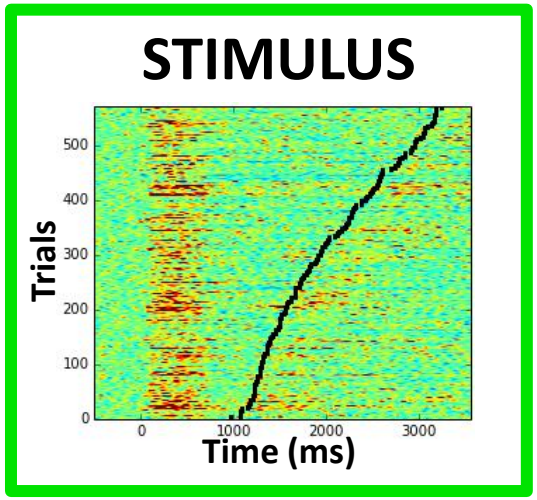
Total coverage – 1804 electrodes recorded

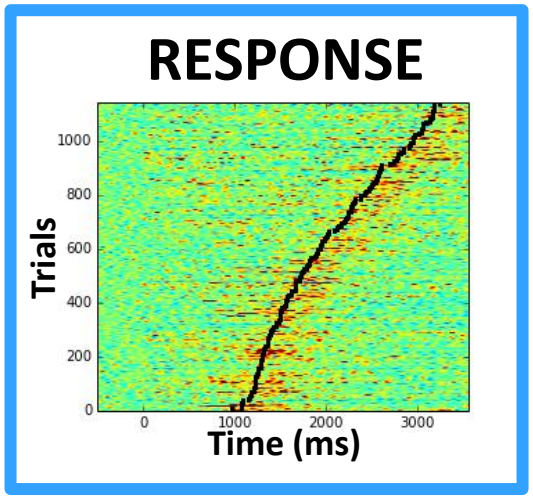


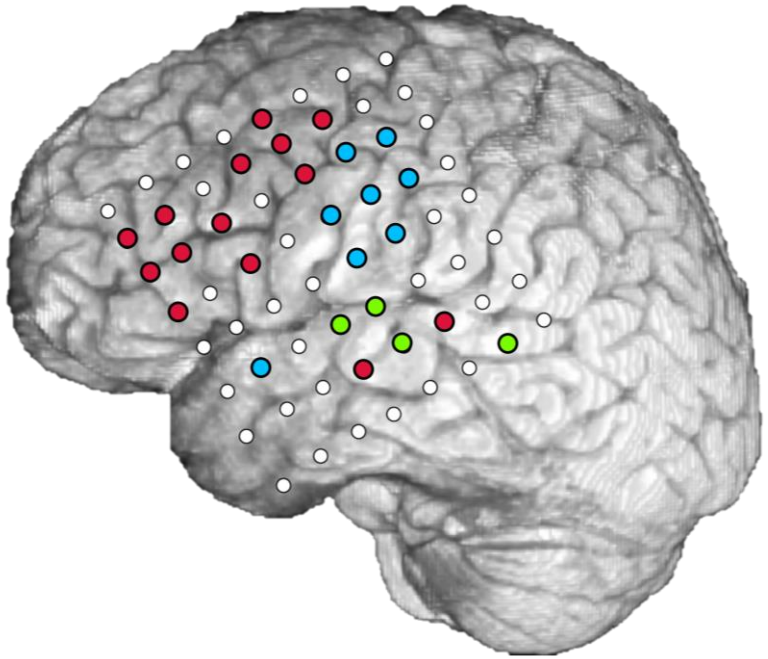
Active Electrodes – 53% of all electrodes

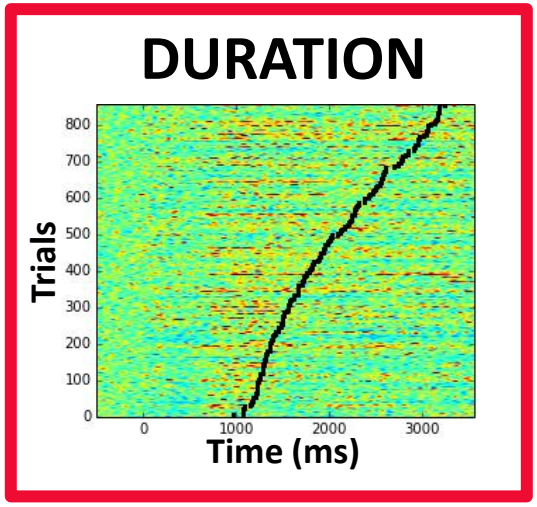


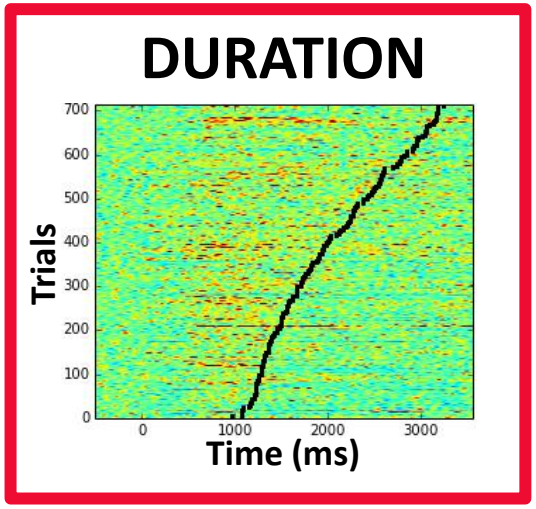
Consistent temporal patterns of HG activation

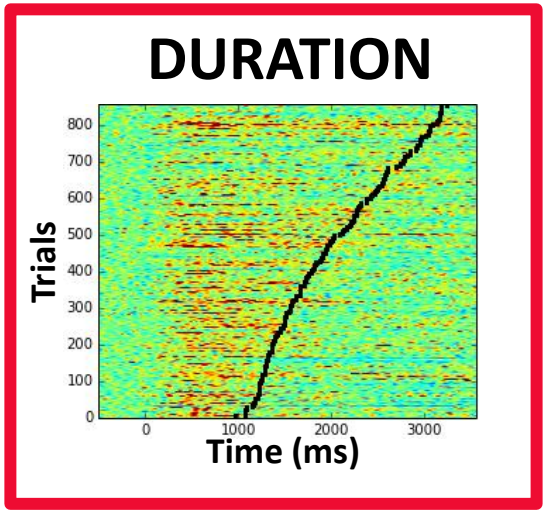






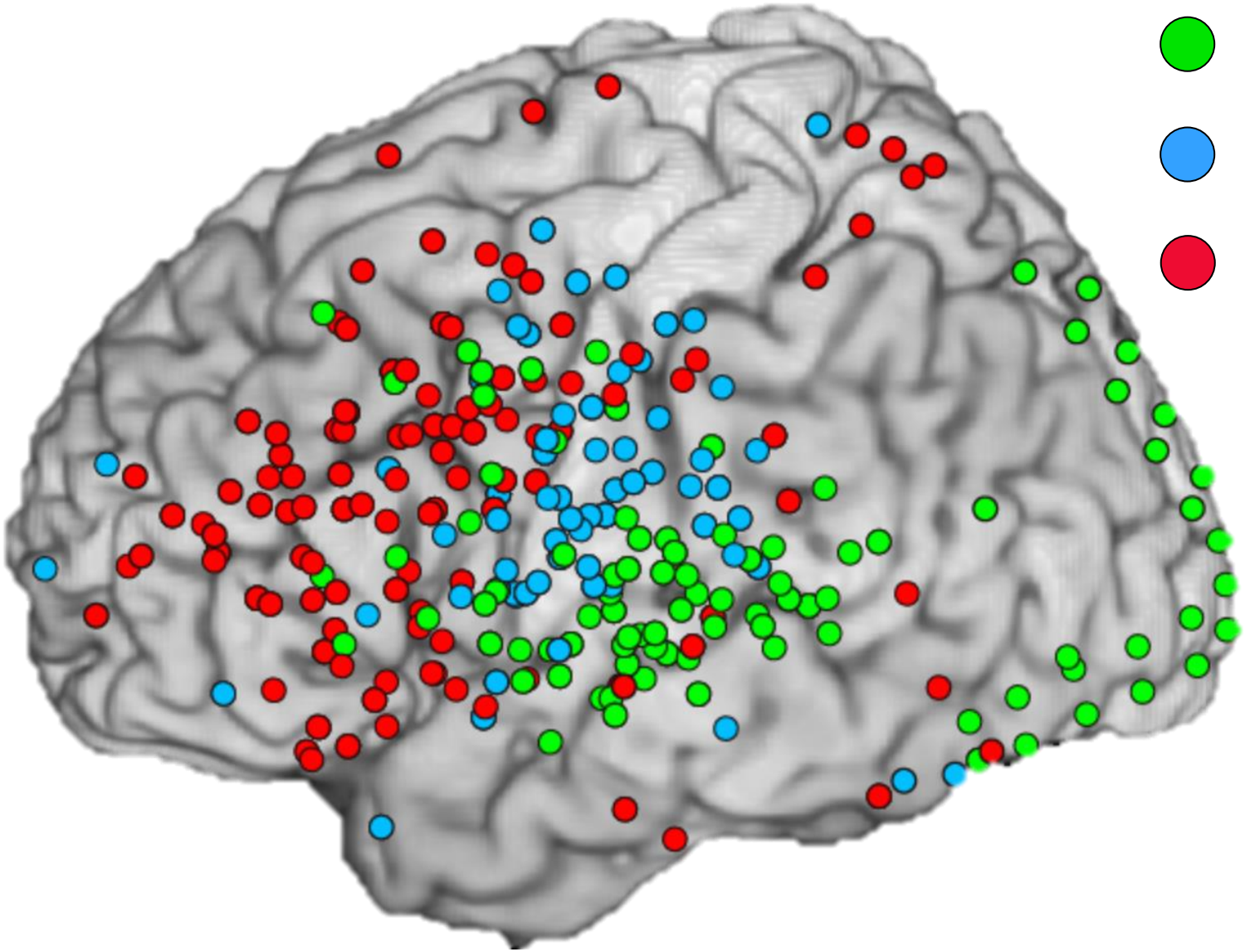






1 Subject, Task: Antonym Generation

Consistent temporal patterns of HG activation



All left hemisphere subjects

Consistent temporal patterns of HG activation

Motor

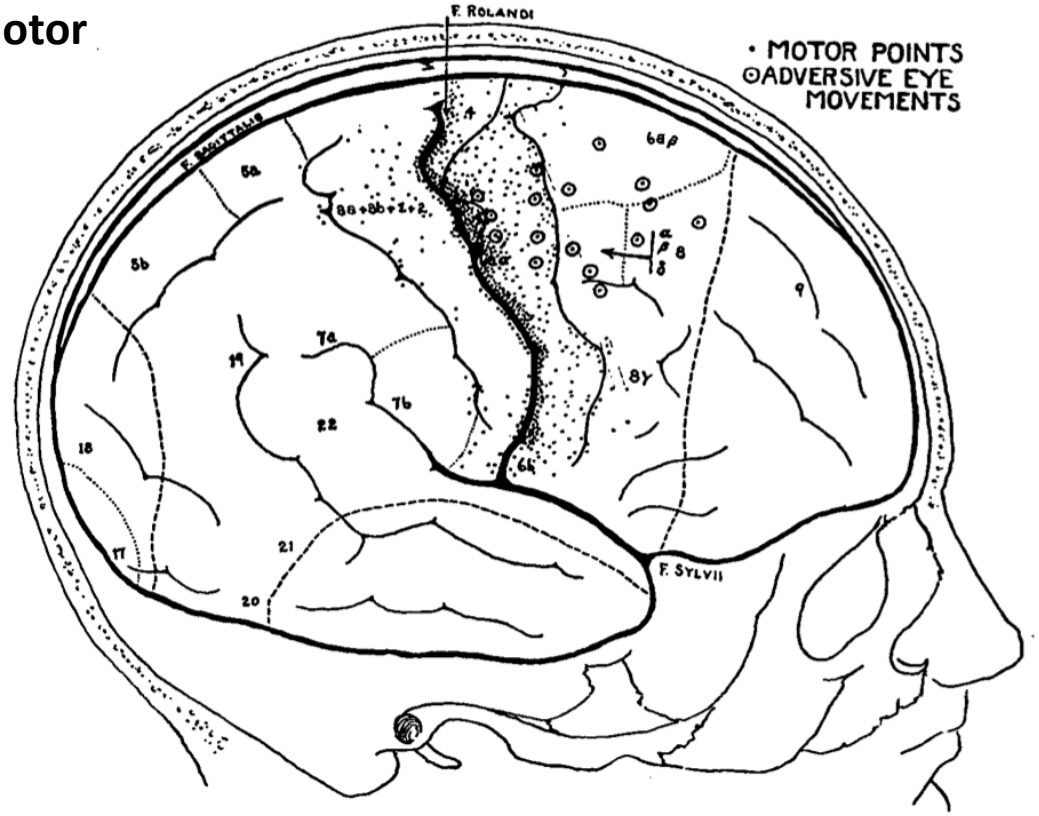
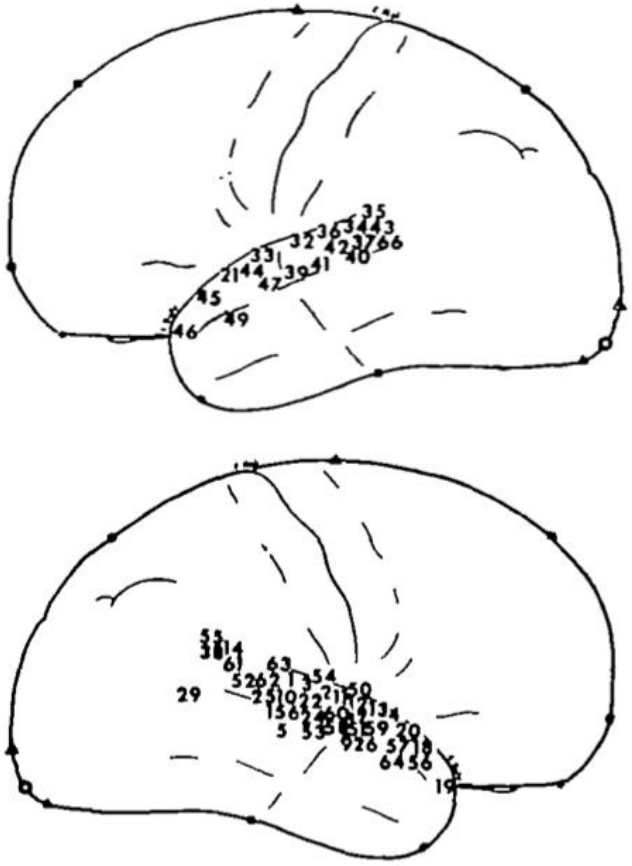


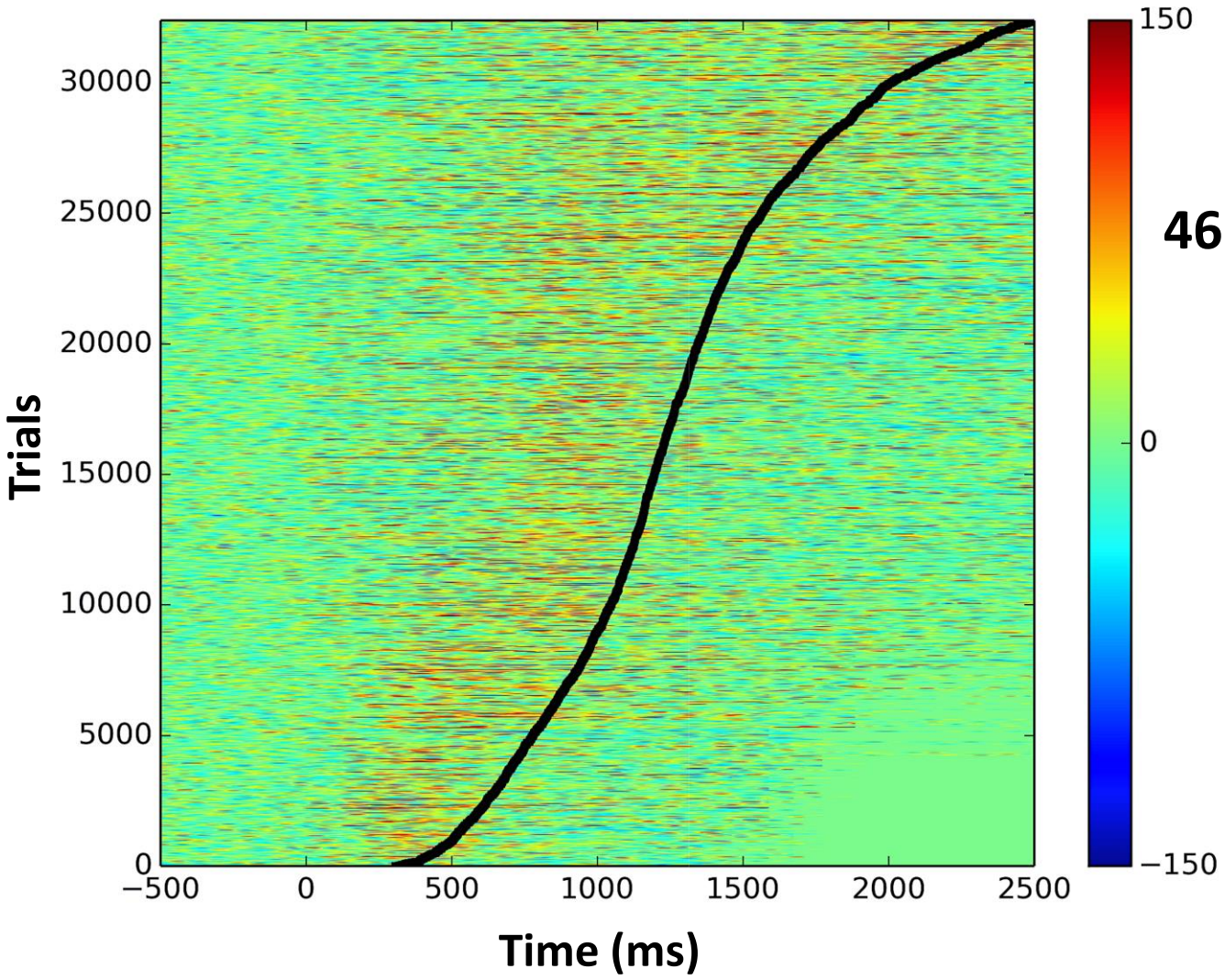
FIG. 29.—Motor cortex. Each black dot represents an actual motor response. The number 4 indicates where Area 4 extends from the anterior wall of the fissure on to the surface, according to Vogt. The remainder of the outer surface of the precentral gyrus is made up of Area 6*a alpha*. ⊙ = conjugate movements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

Auditory



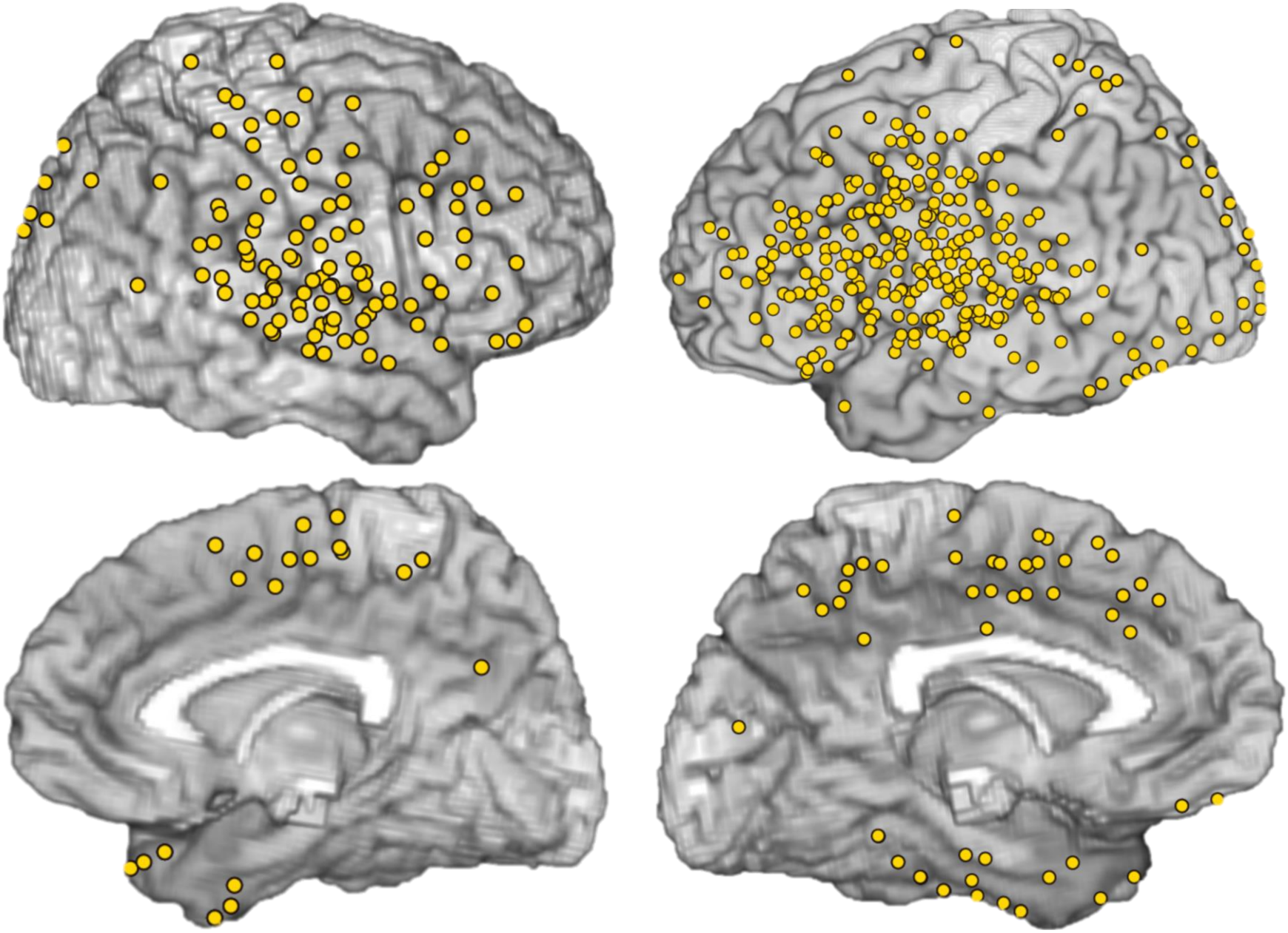
Penfield & Boldrey, 1937 ; Penfield & Perot, 1963

Duration: sustained activation from stimulus through response

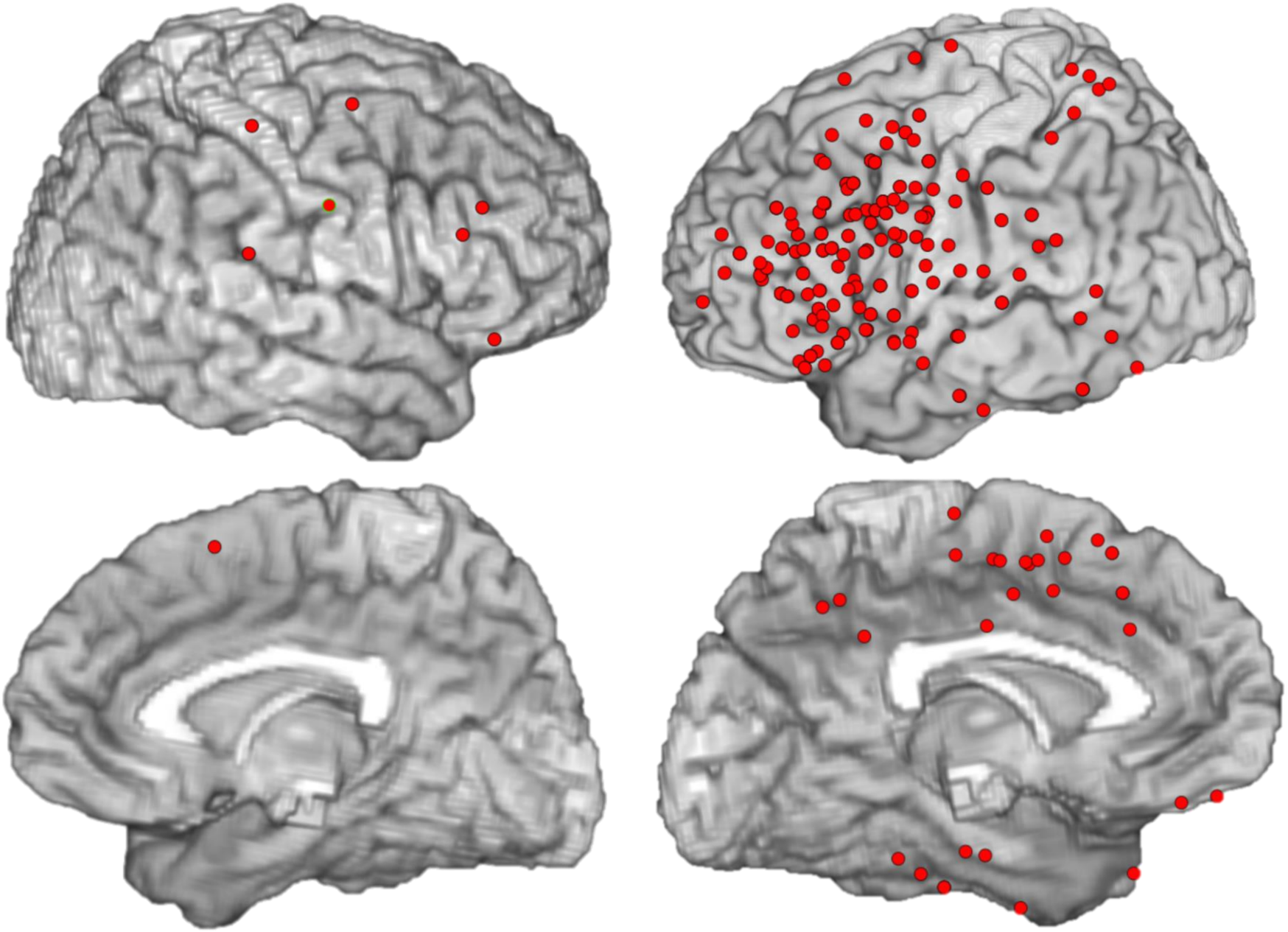


46 duration clusters
283 electrodes
33,000 trials

Active Electrodes



29% of active electrodes are duration



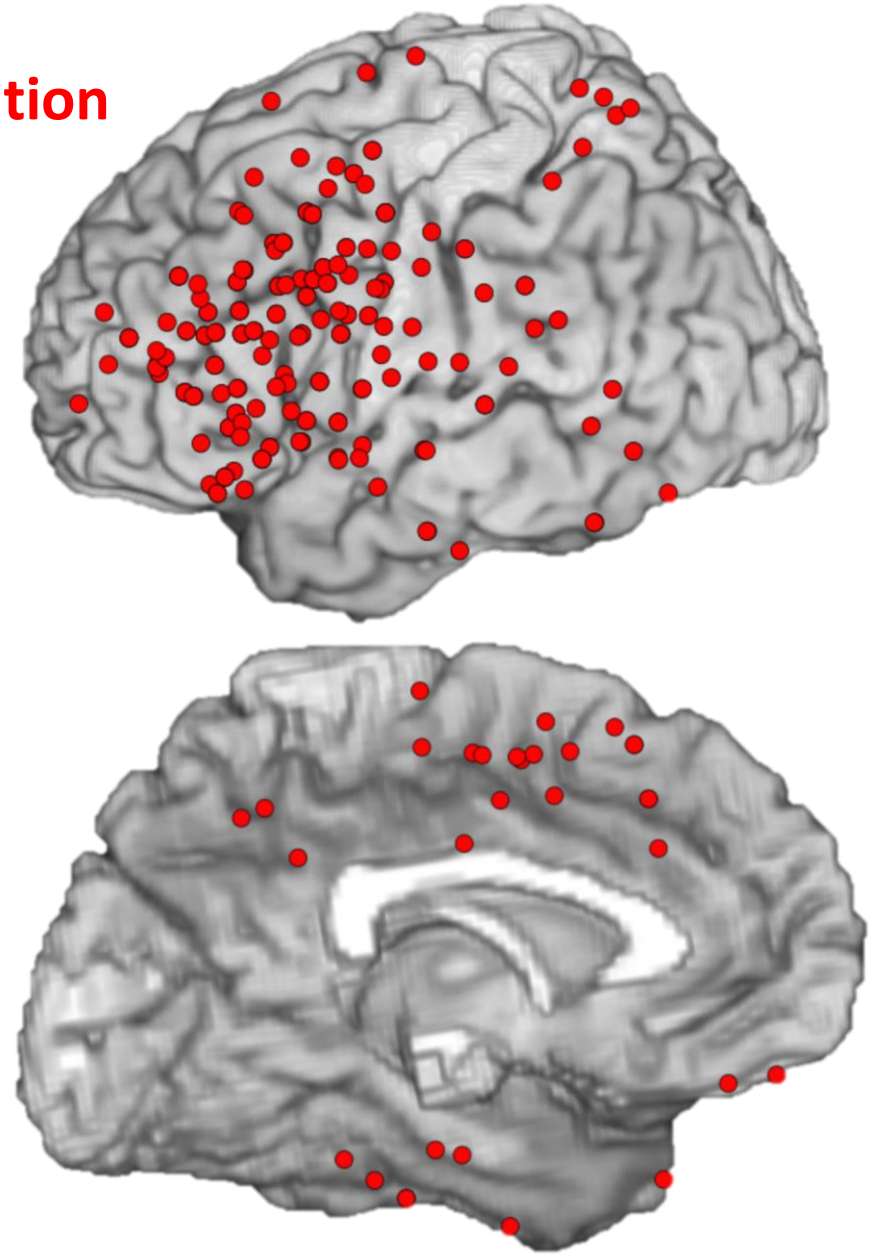
Left Hemisphere:

33% of active electrodes are duration

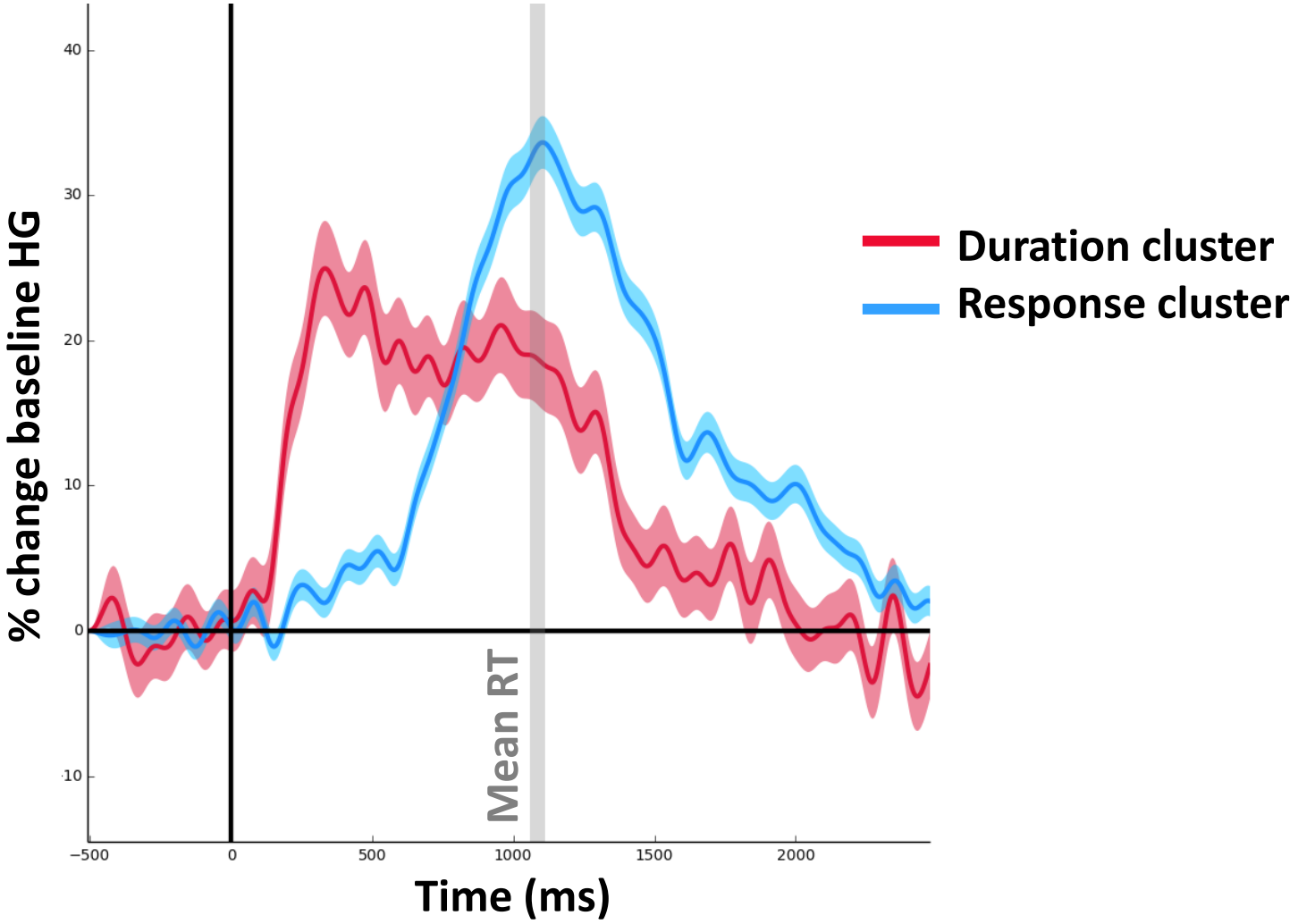
Left Frontal Cortex:

53% of active electrodes in left frontal cortex are duration

71% of active electrodes in left MFG are duration

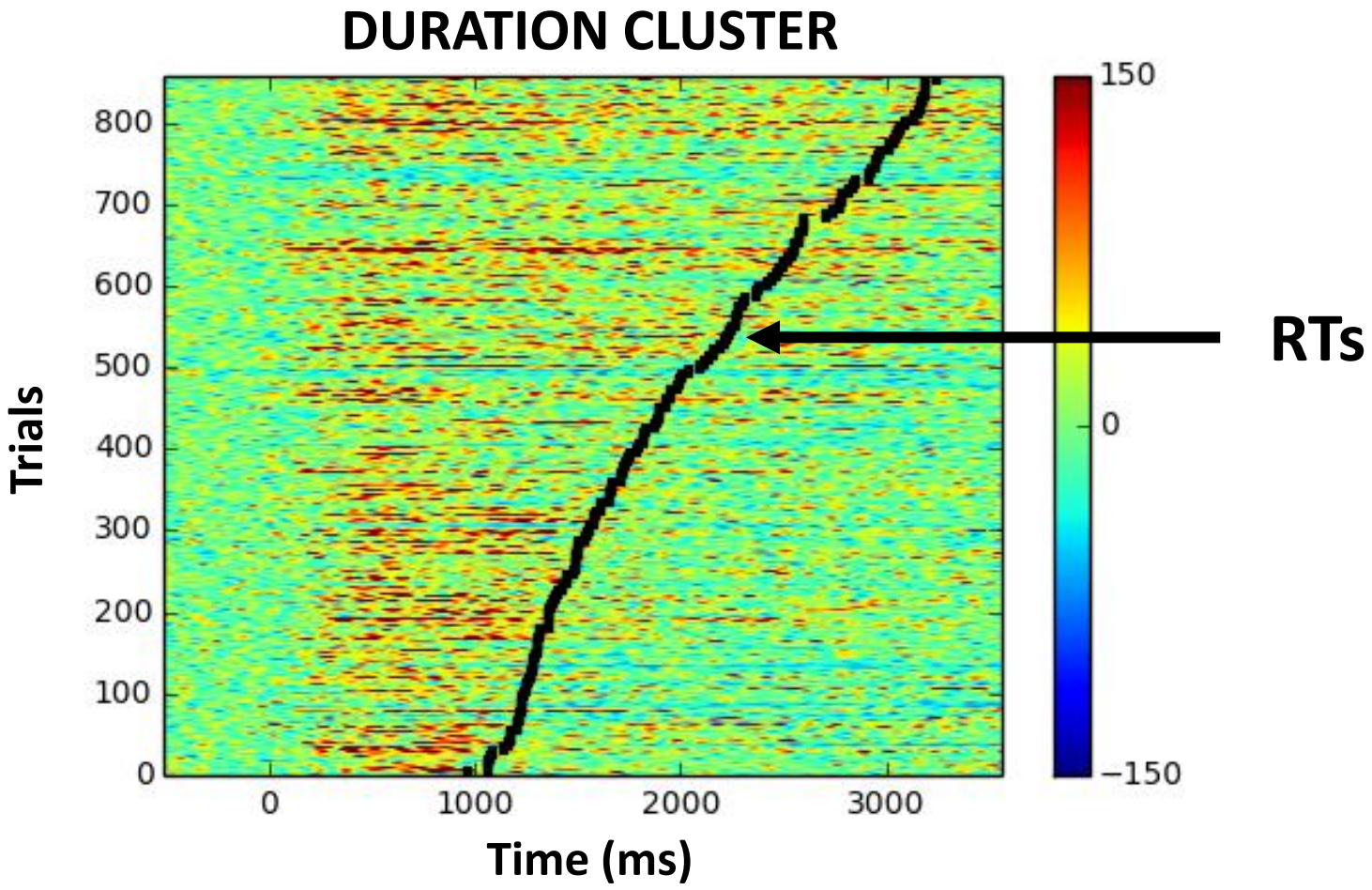


Duration clusters peaks precede response cluster peaks

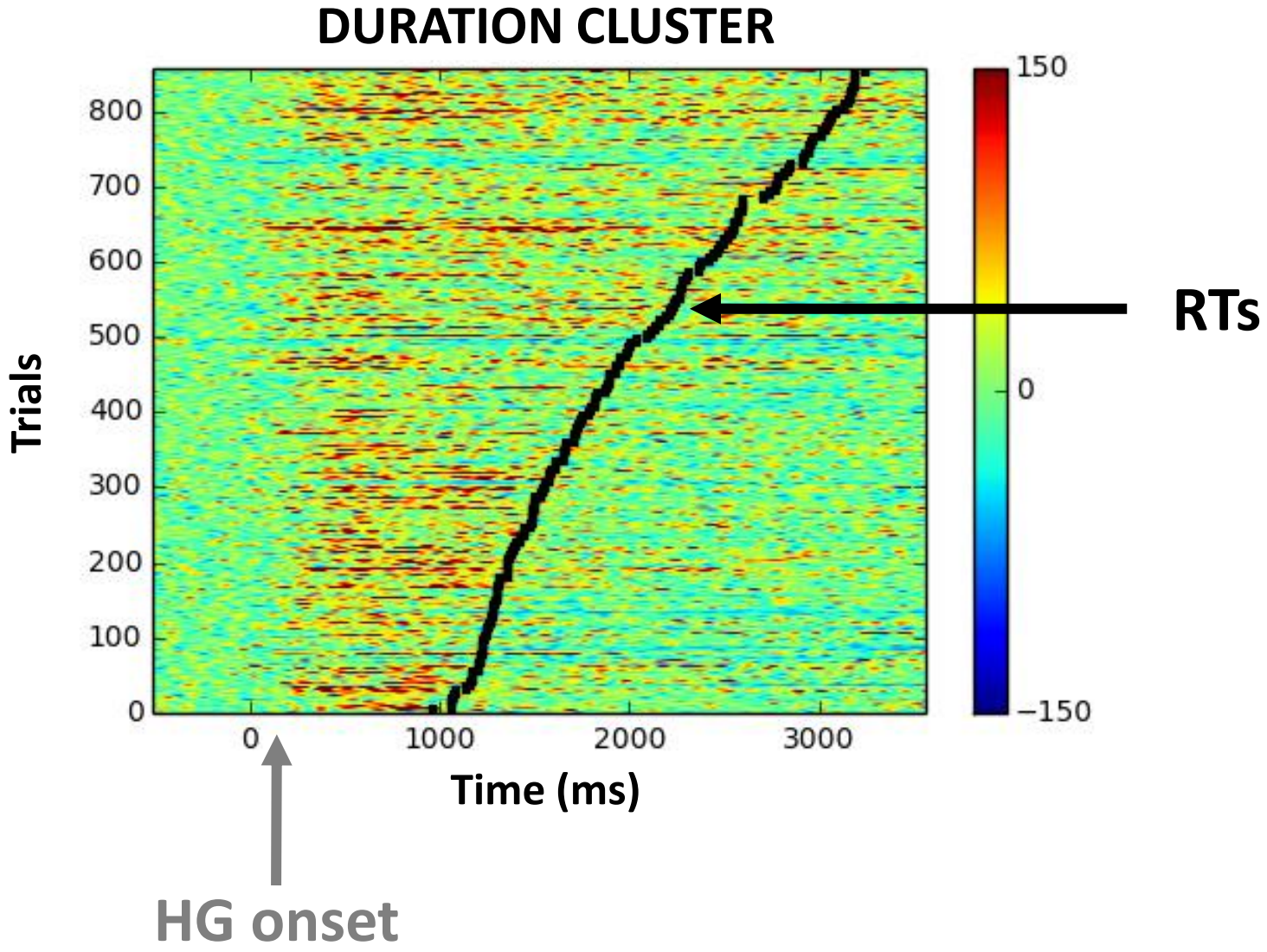


1 subject, Task: Self Referential - Visual

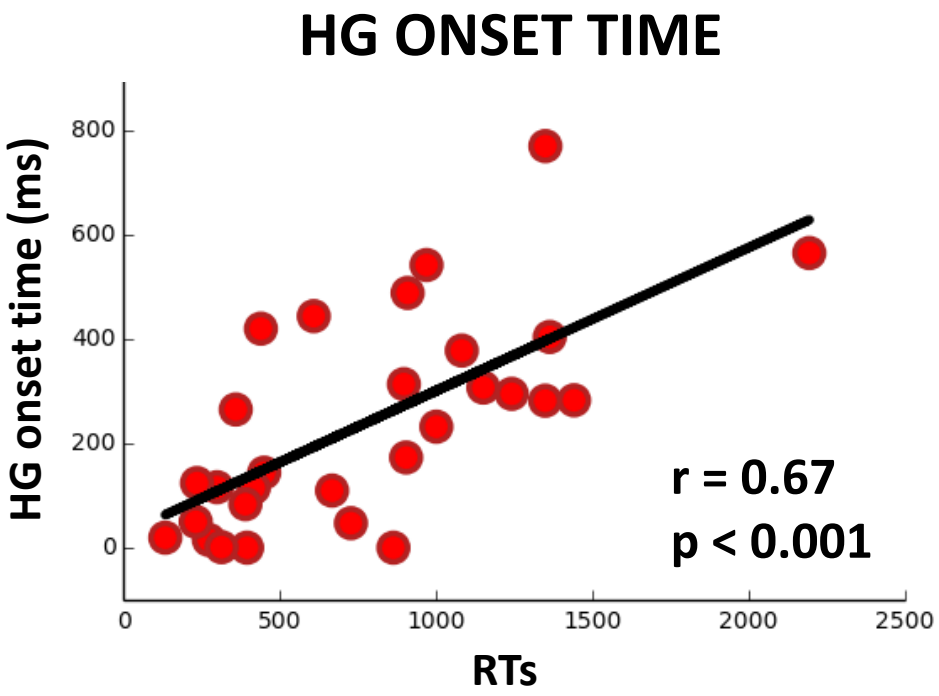
Features of the HG signal



Features of the HG signal



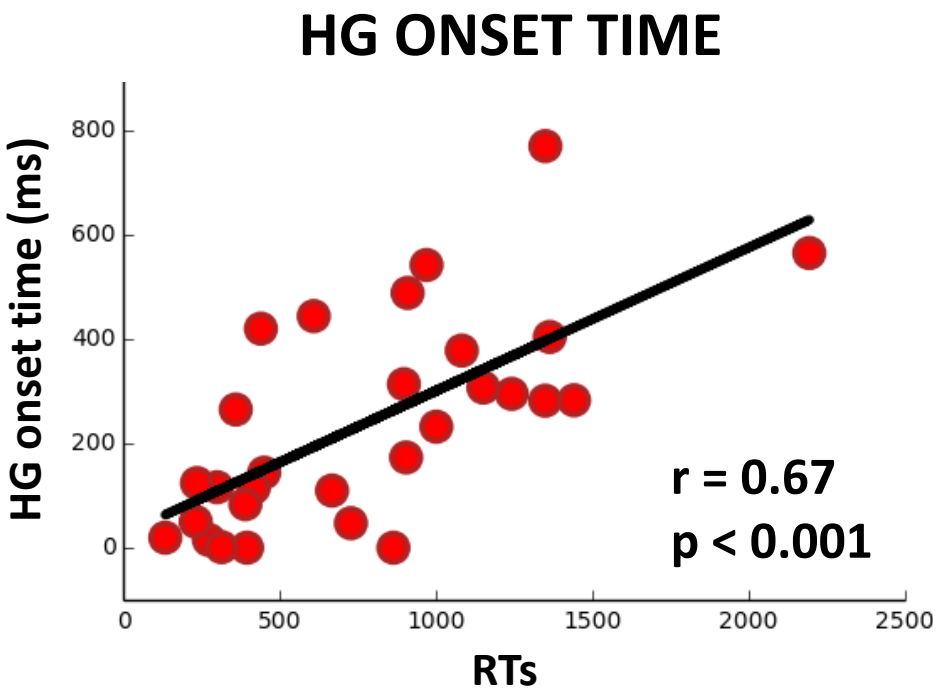
HG onset times correlate with RT

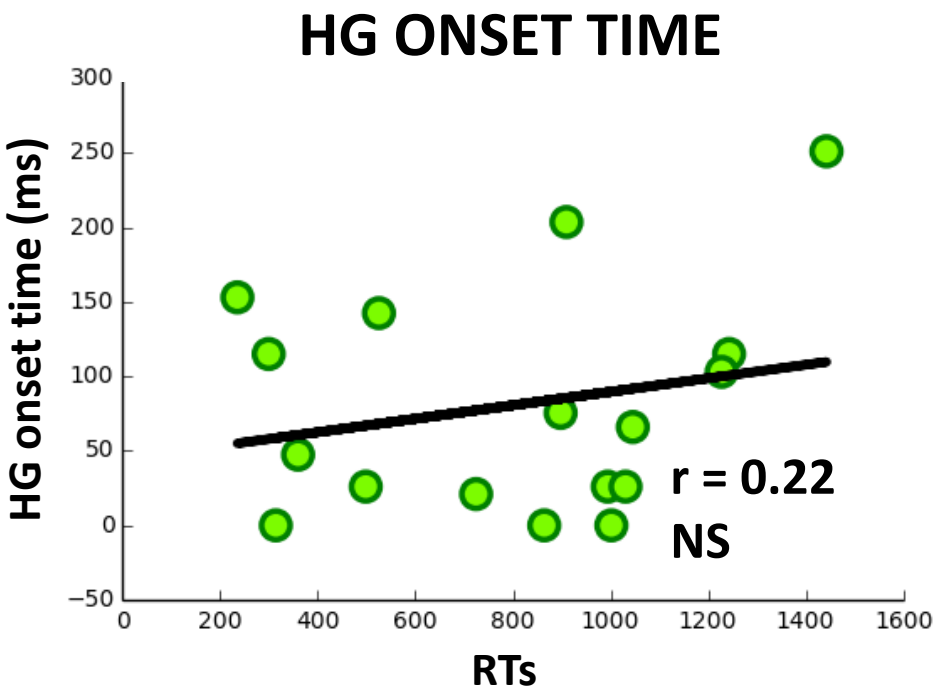


DURATION CLUSTERS

Across all tasks and subjects

HG onset times correlate with RT

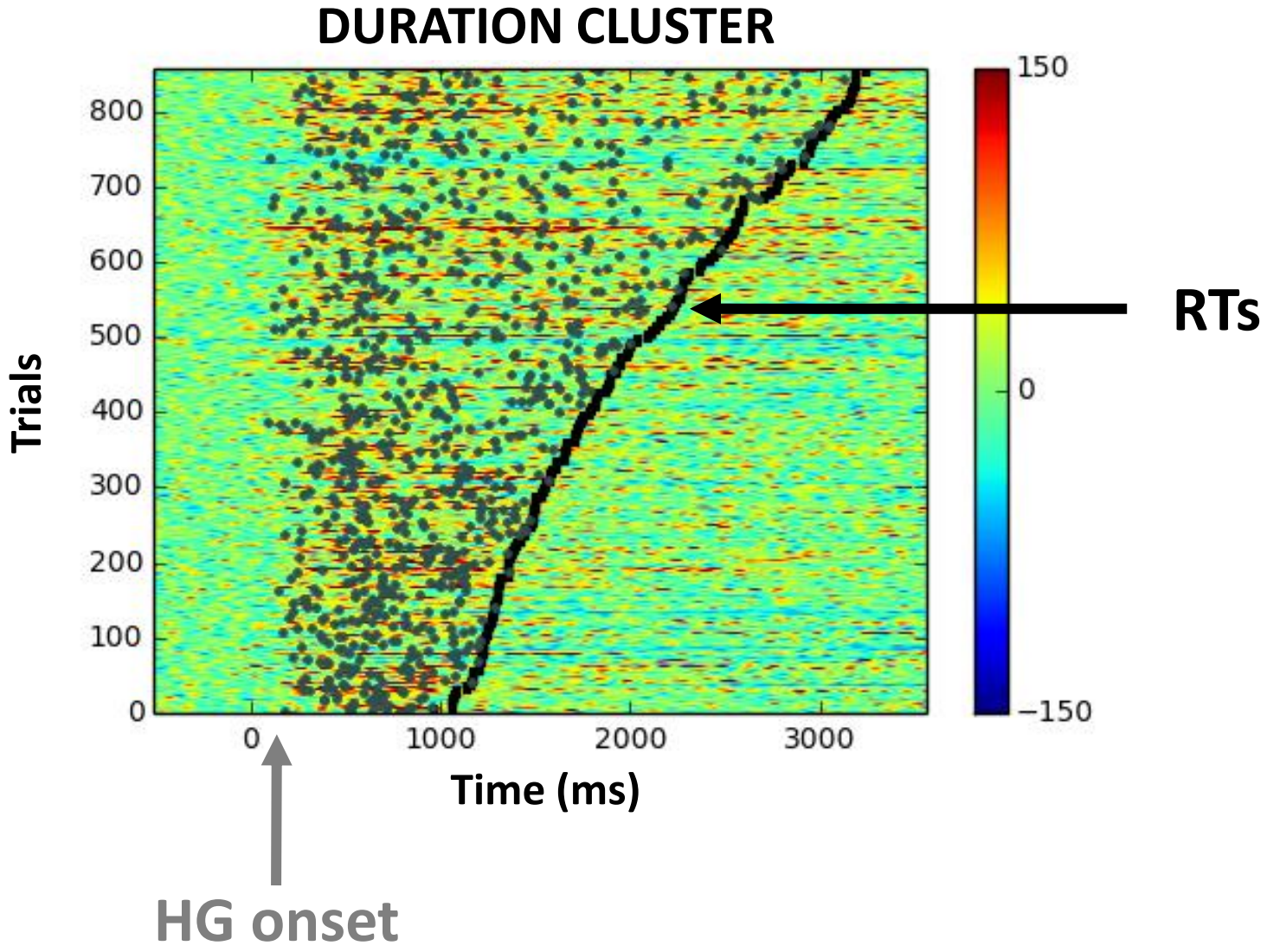




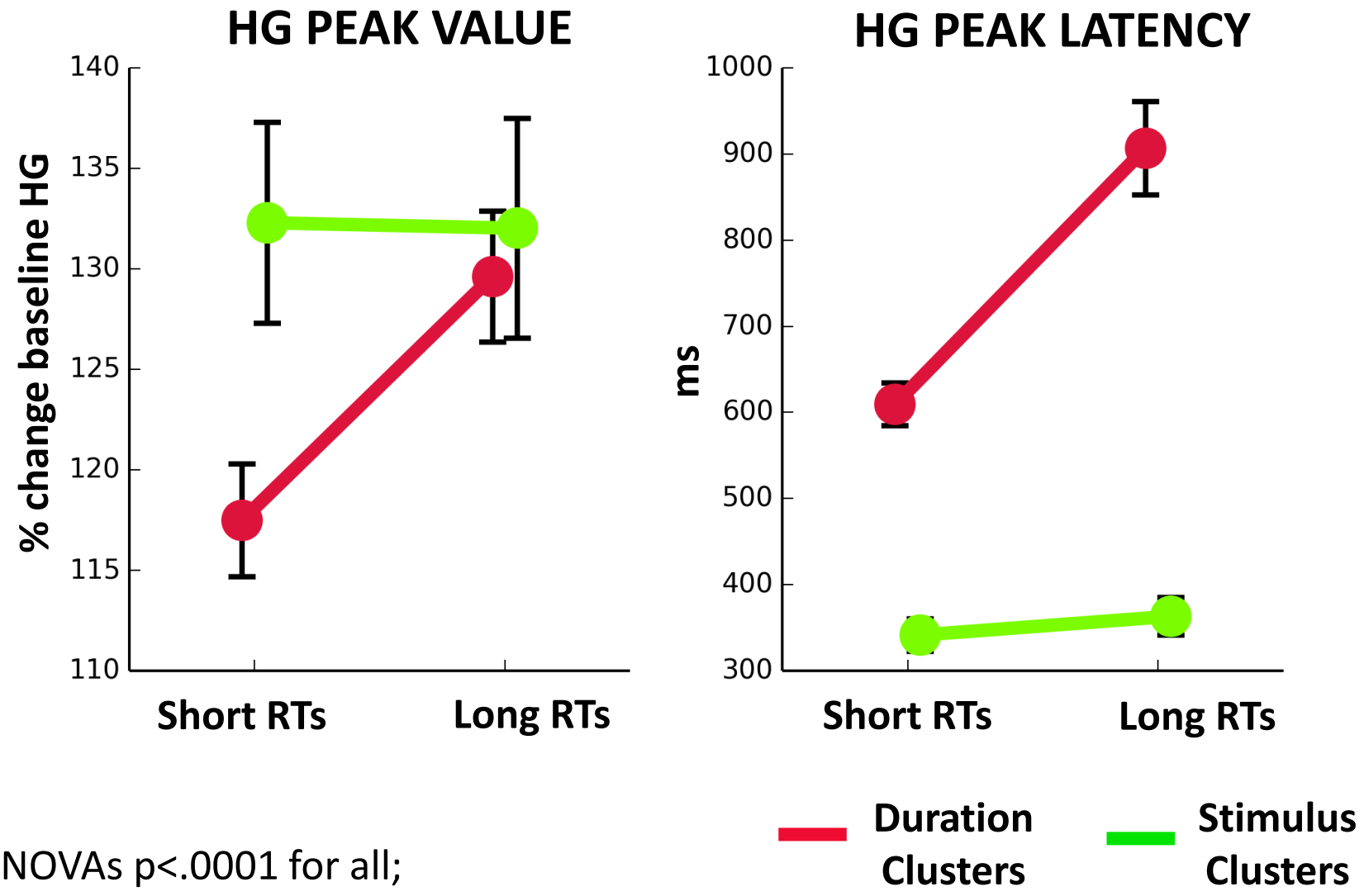
DURATION CLUSTERS
Across all tasks and subjects

STIMULUS CLUSTERS
Across all tasks and subjects

Features of the HG signal

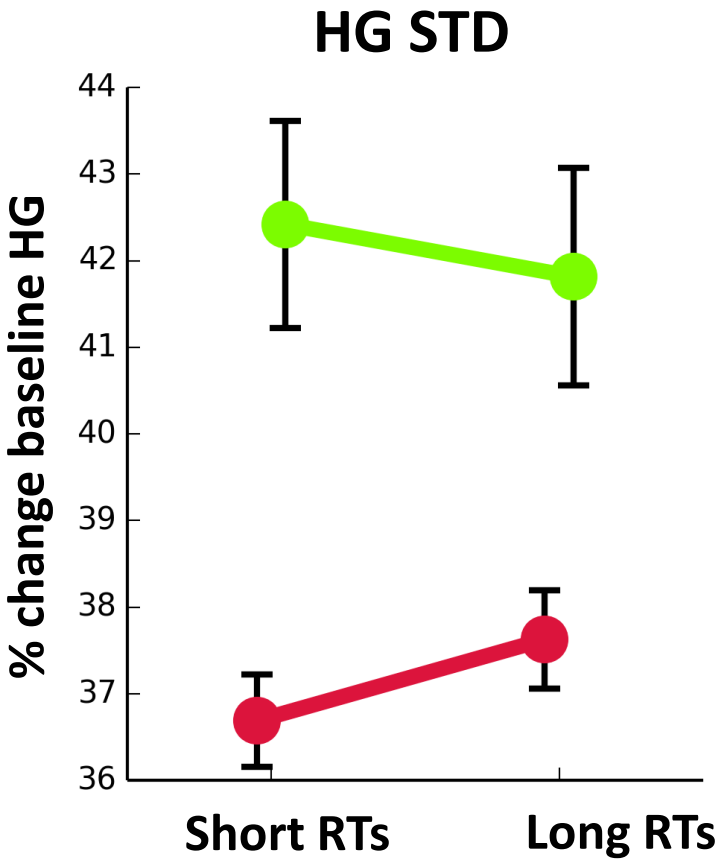


Increased HG peaks and latencies for longer RTs



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

Increased noise for longer RTs



Duration Clusters

Stimulus Clusters

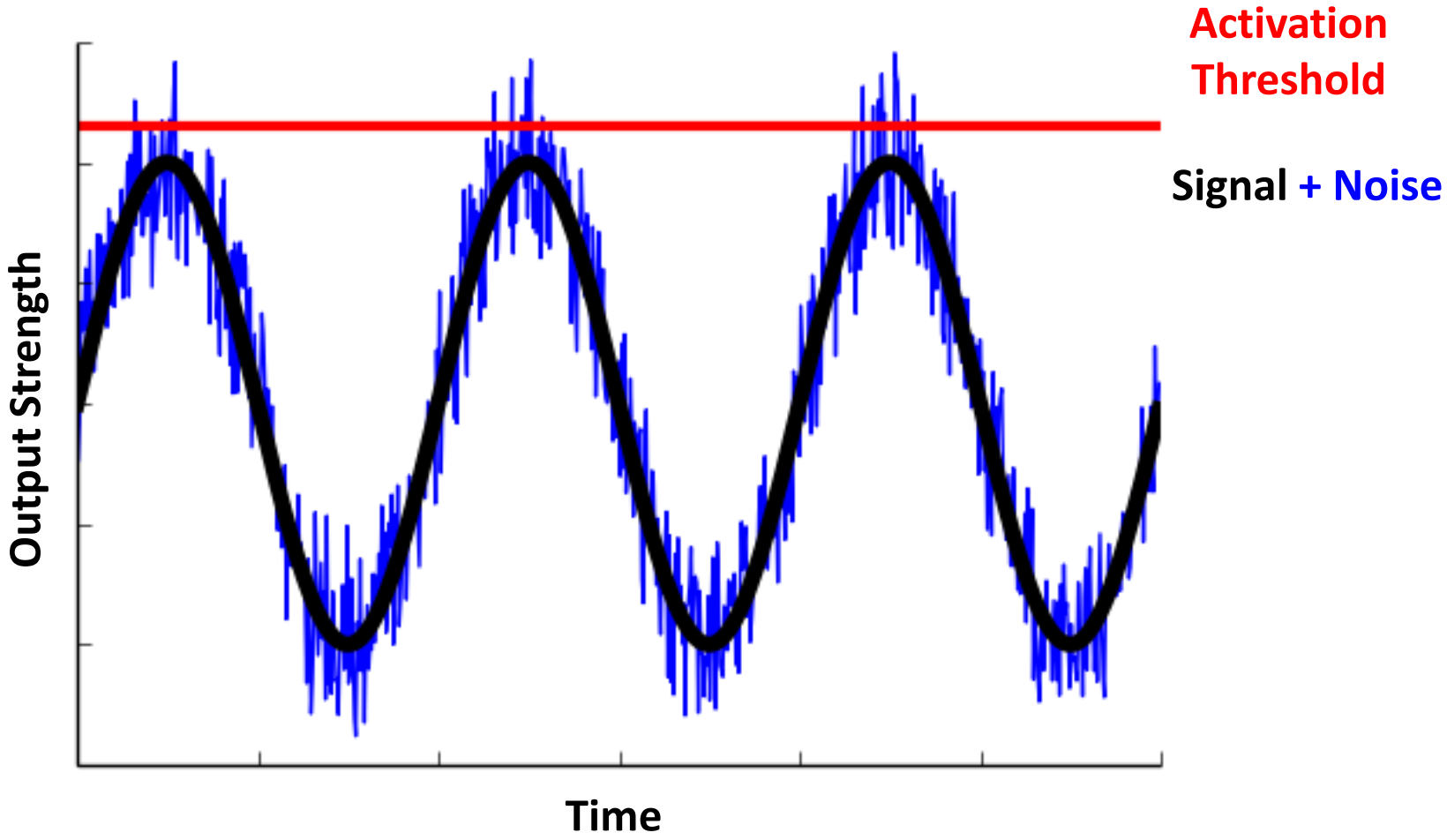
2 x 2 ANOVAs p<.0001 for all;

For duration clusters: long > short, p<.001

Role of noise in decision-making?

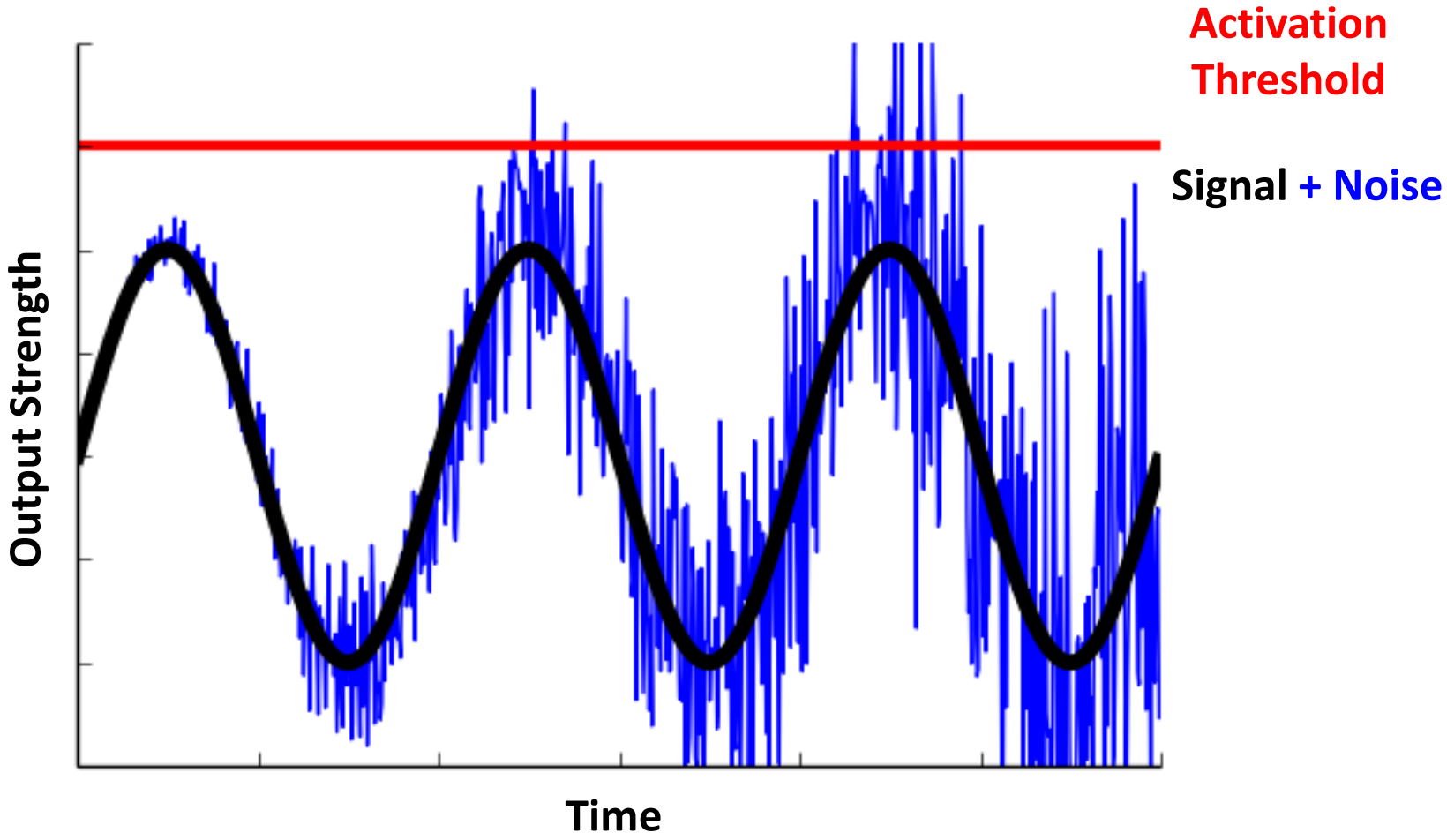
1. Stochastic Resonance

Stochastic Resonance

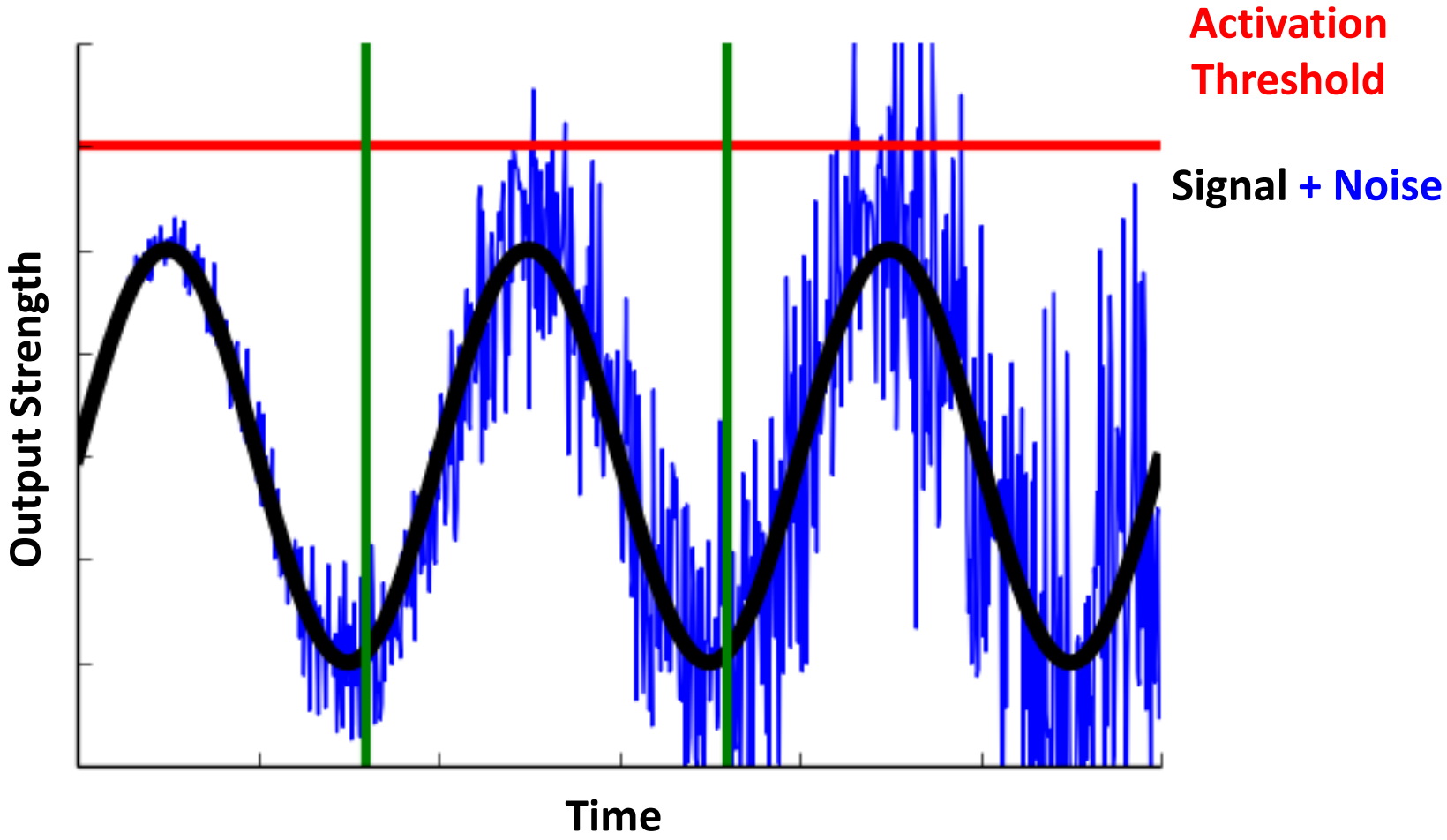


McDonnell & Abbott, 2009; Buzsaki, 2011

Stochastic resonance with increasing noise



BUT: Stochastic resonance predicts more noise for short RTs



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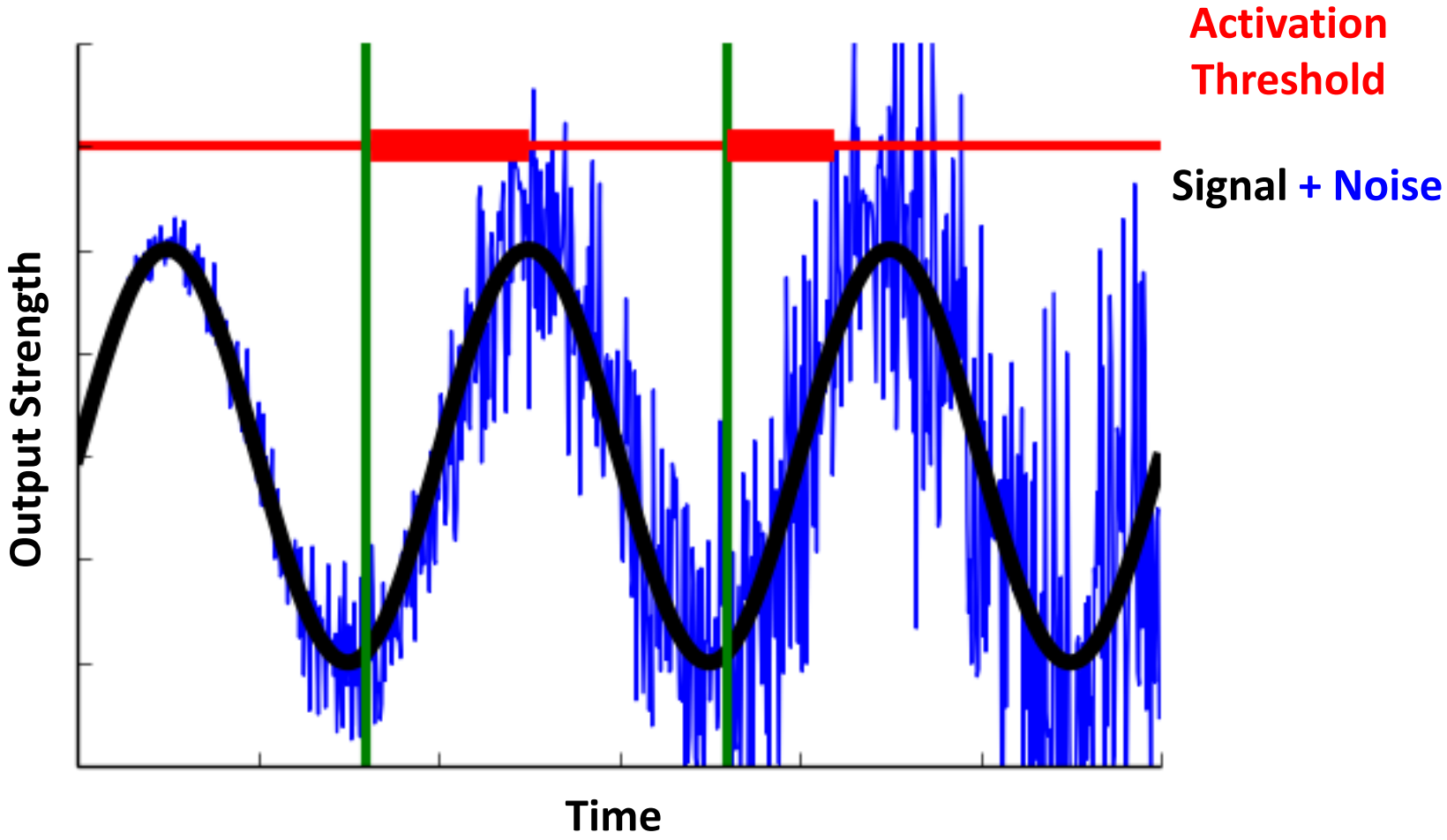
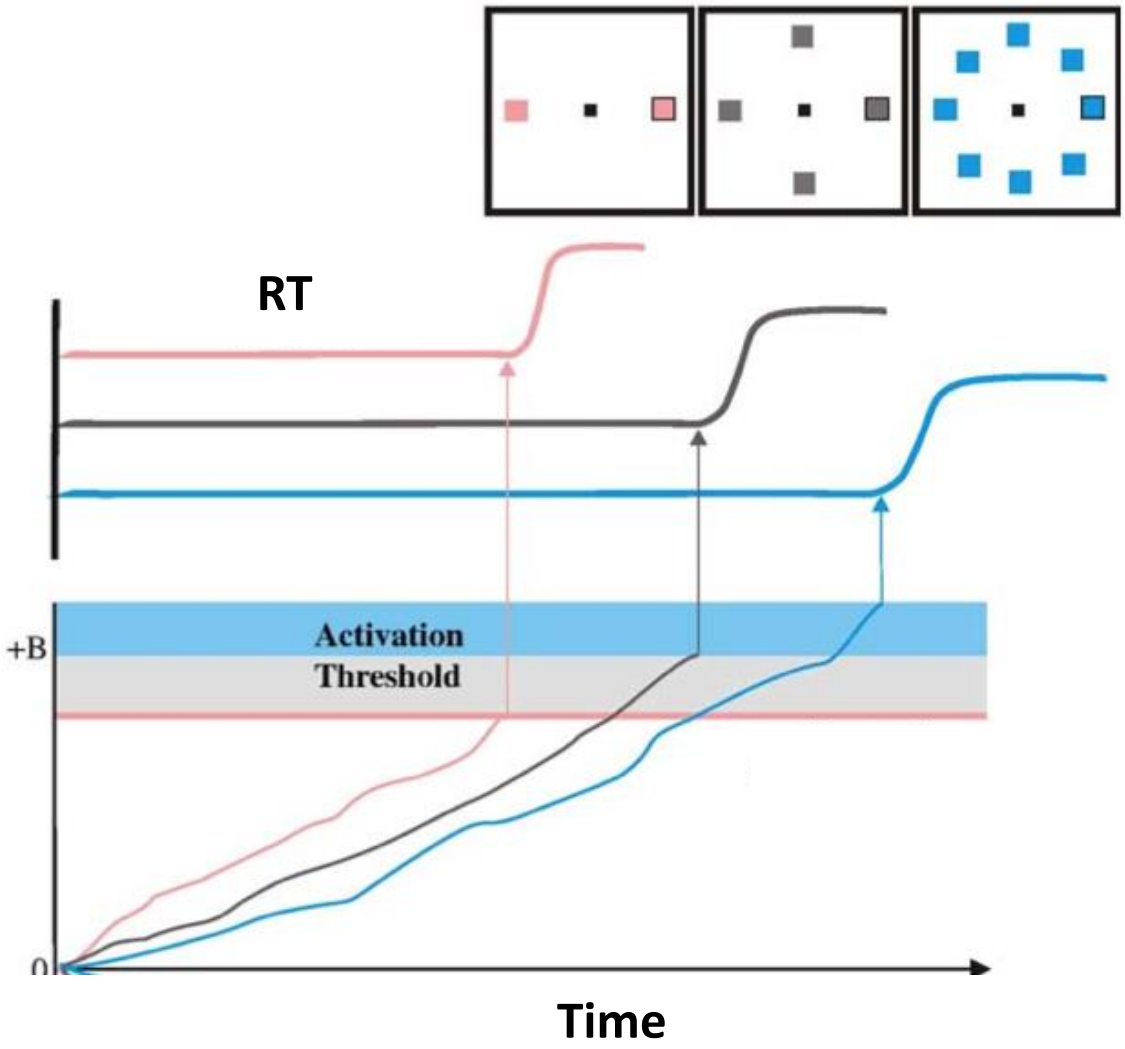


Role of noise in decision-making?

1. Stochastic Resonance

1. Speed-Accuracy Tradeoff
   (increase in activation threshold)

Increasing activation threshold with increasing number of options



Opris & Bruce, 2005

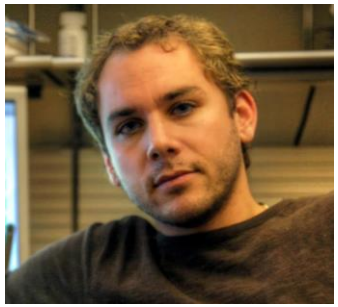
Conclusions

- 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.

THANKS…


Robert Knight


Avgusta Shestyuk


Adeen Flinker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