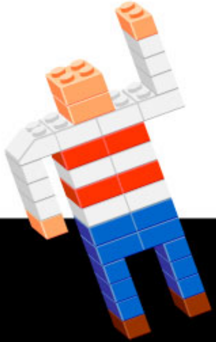
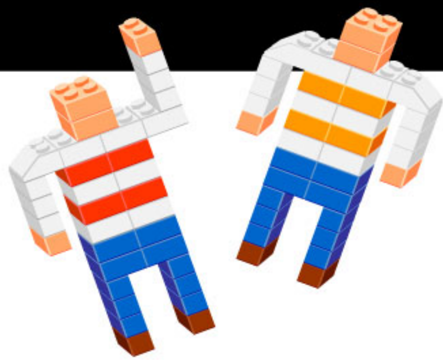
ISSA summer school 2017
30/05/2017



Neural correlates of attention and readiness

Noriko Yamagishi
NICT CiNET, Osaka Univ., ATR



Consciousness and ...

Attention

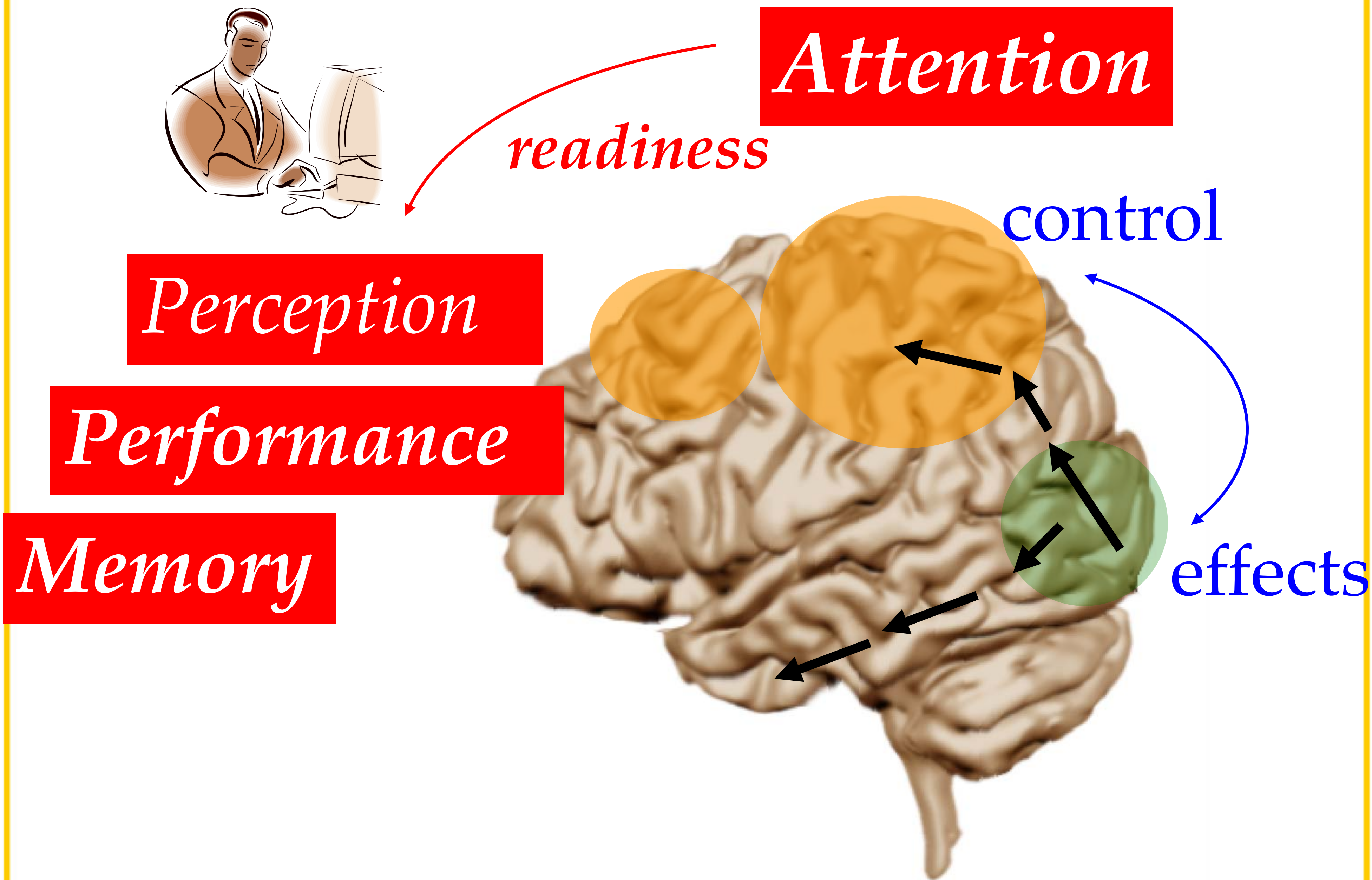
Readiness

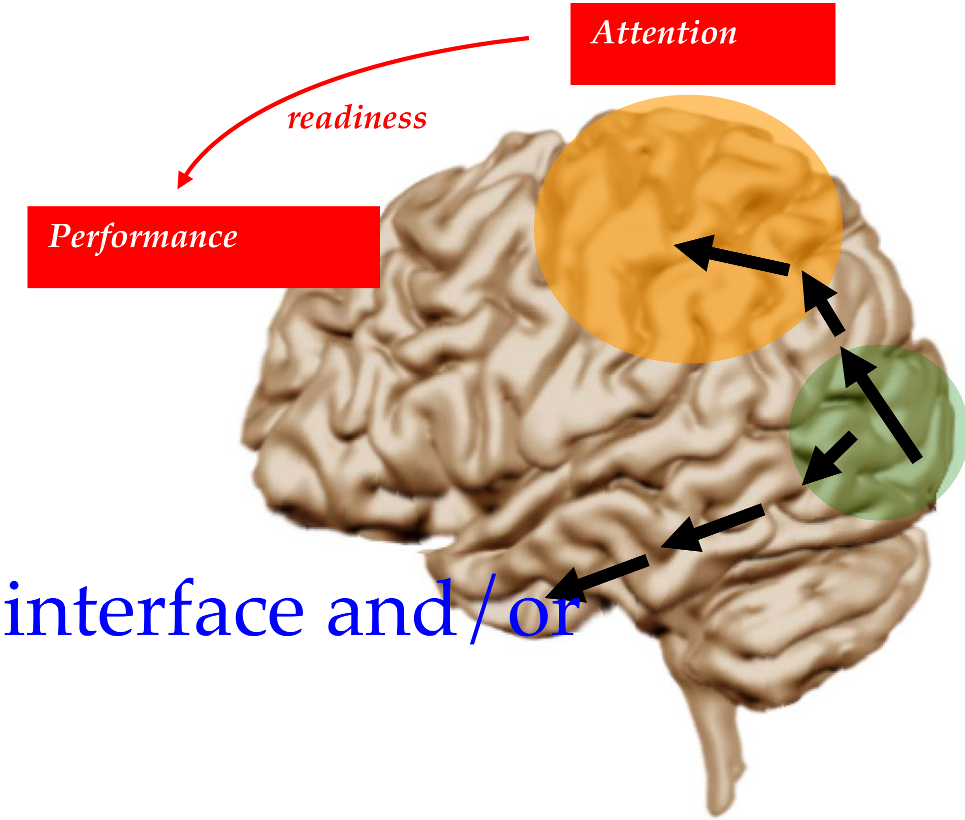
Consciousness and ...

Attention

Attention
demo

Attention mechanisms

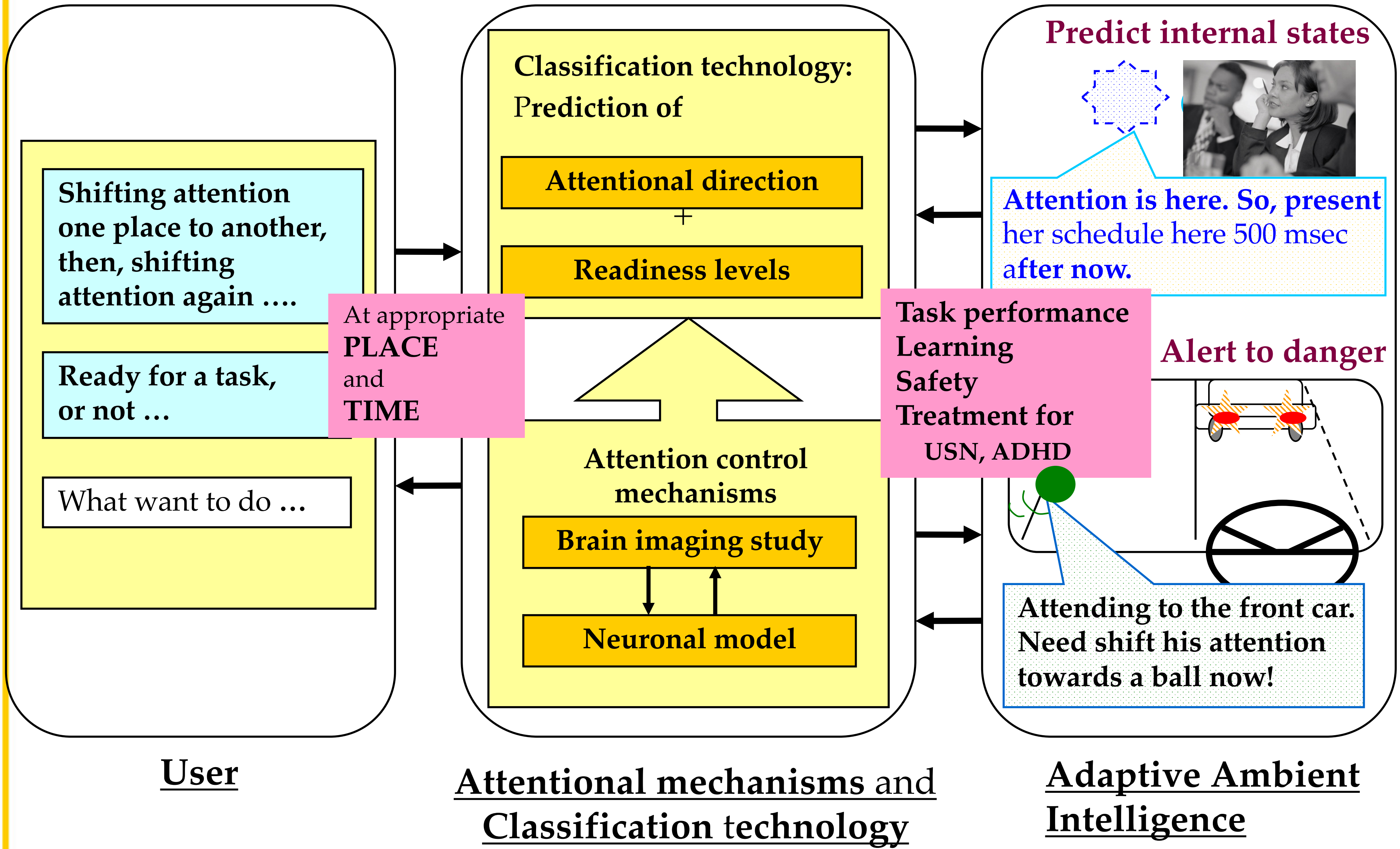

Attention
readiness
control
Perception
Performance
Memory
effects



If …
future communication interface and / or
robot teacher could…

monitor **attentional status** of each user, then it could present useful information at appropriate **place** and **time** for **each individual to enhance behavior performance.**

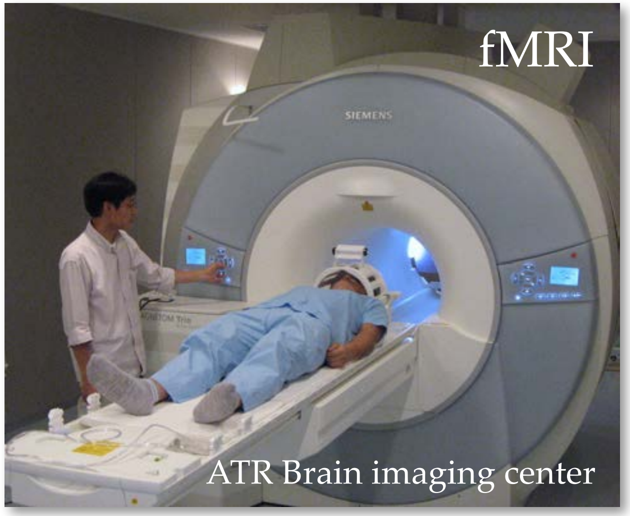
Primary Goal

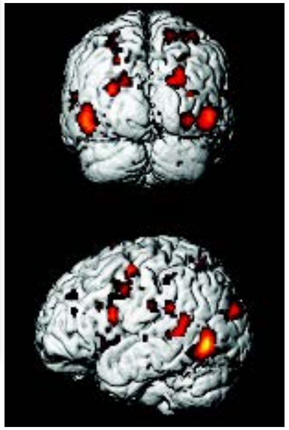


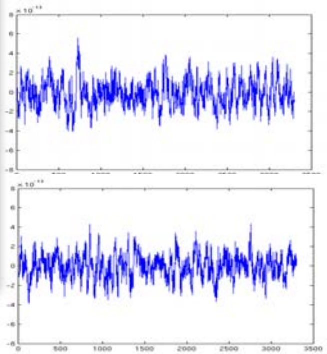
USN: unilateral spatial neglect
ADHD: attention deficit hyper active disorder

Brain imaging study

Brain imaging study

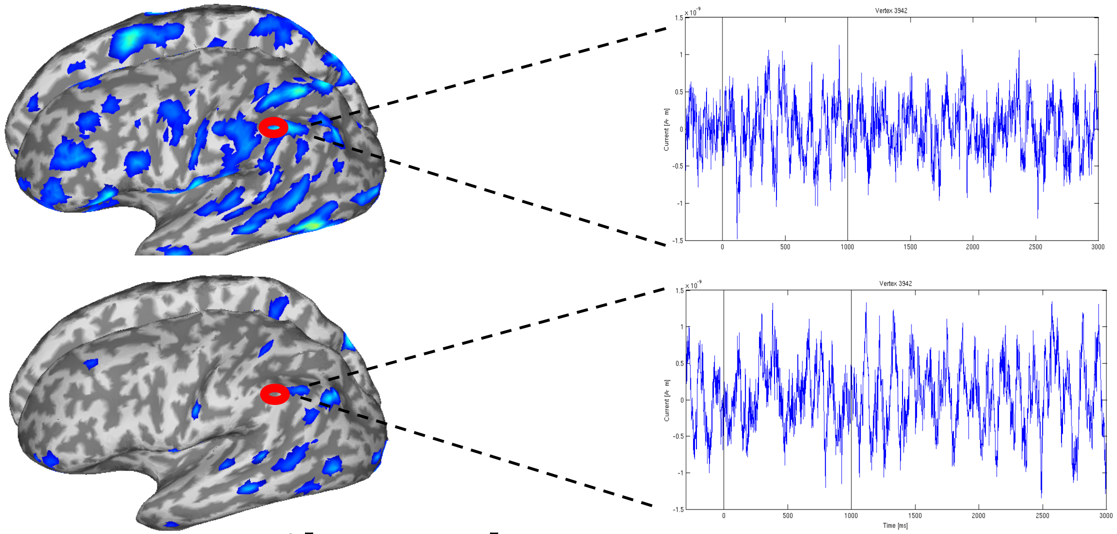






Observer control

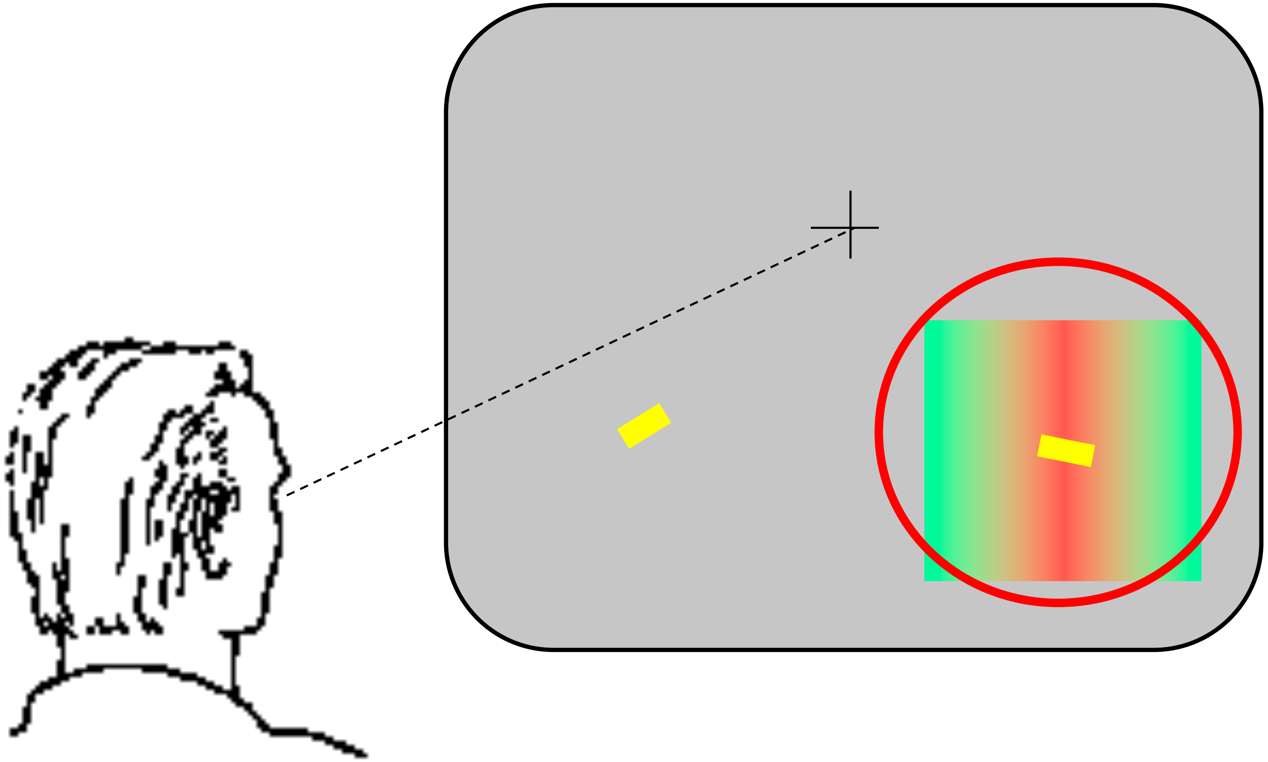
Passive viewing



Mean activities of [0-1000 ms]

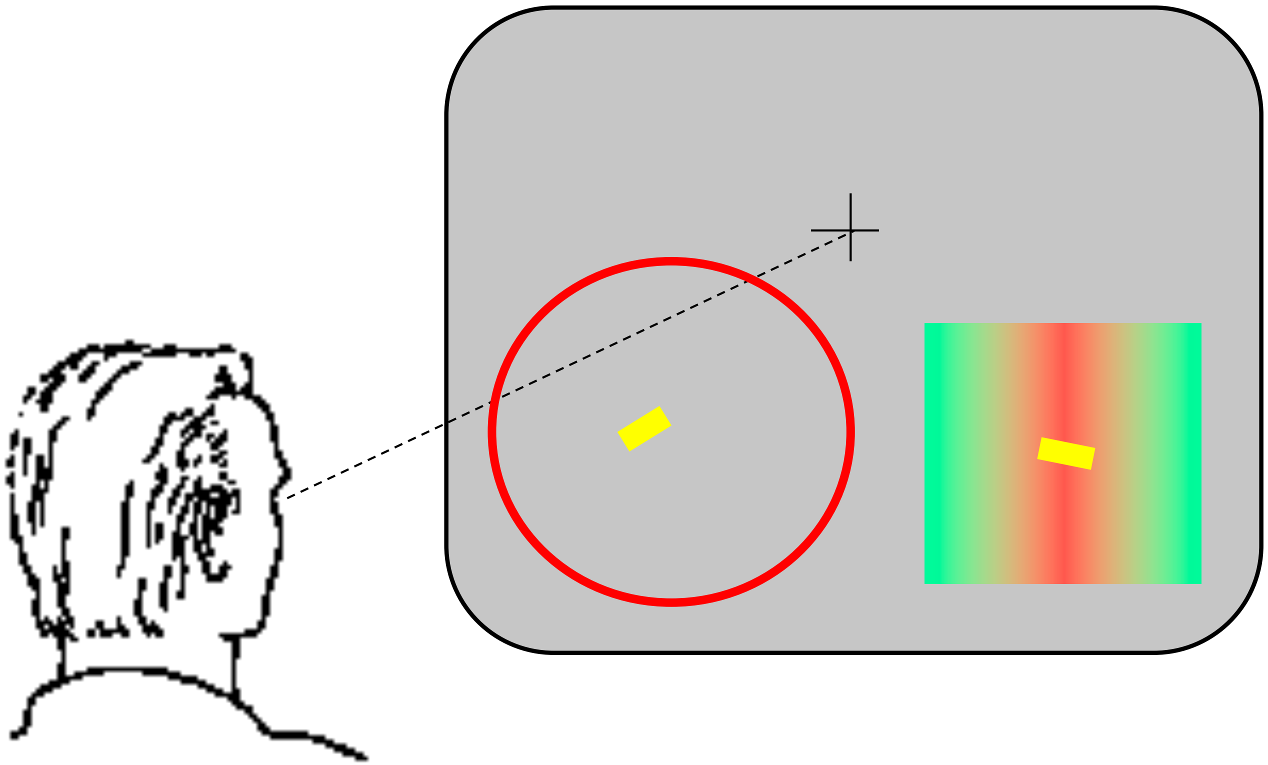
Shifting attention experiment

Attention towards stimulus



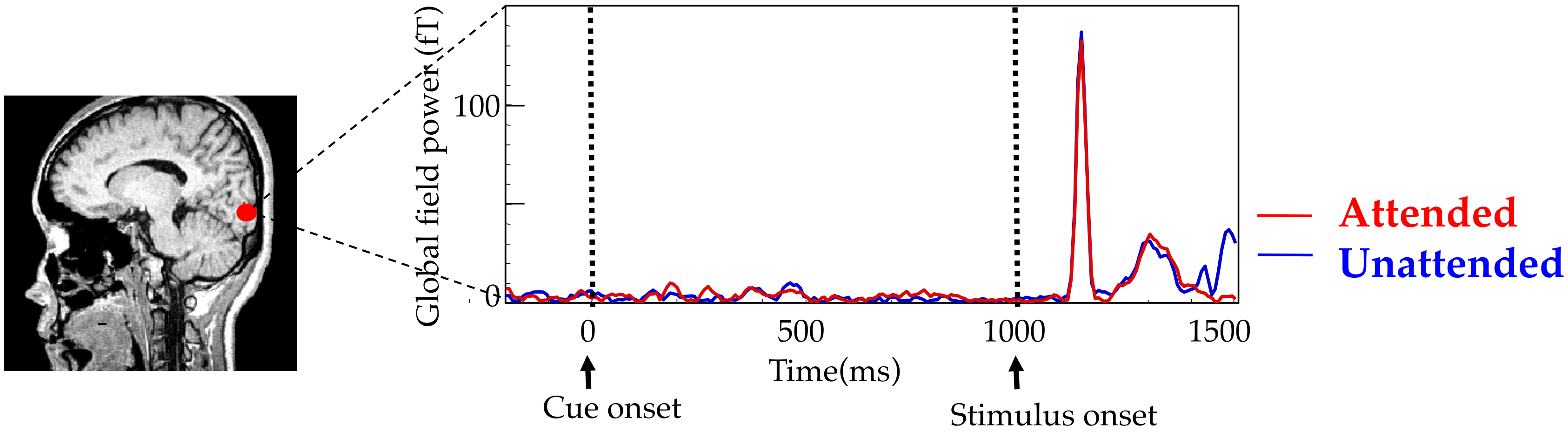
Shifting attention experiment

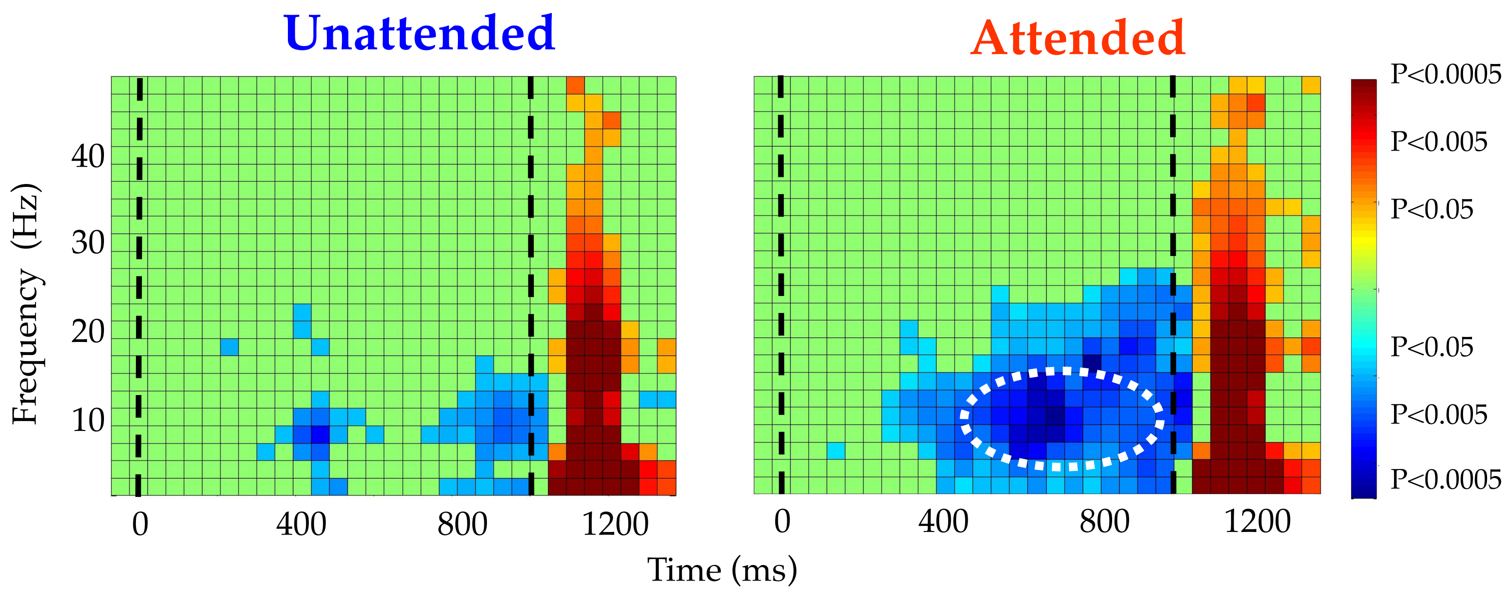
Attention away from stimulus



Attention and neural activity

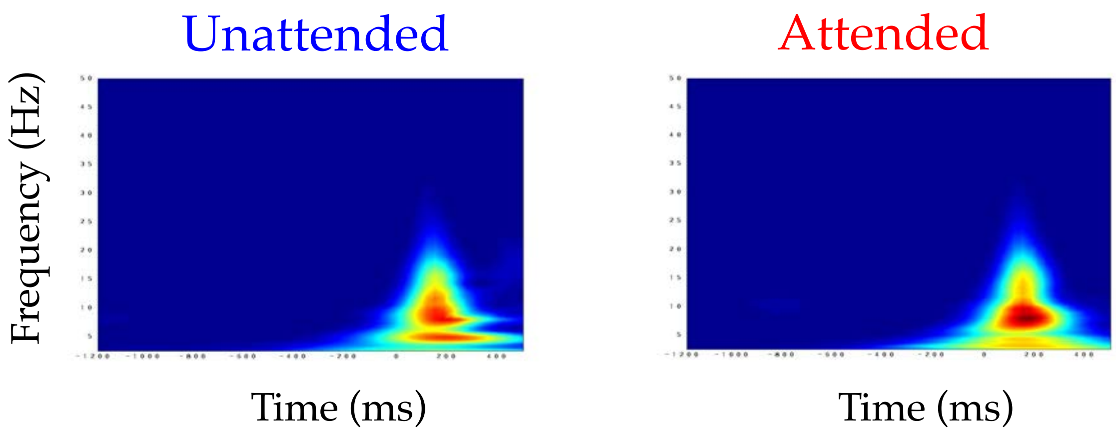
Visual area modulations



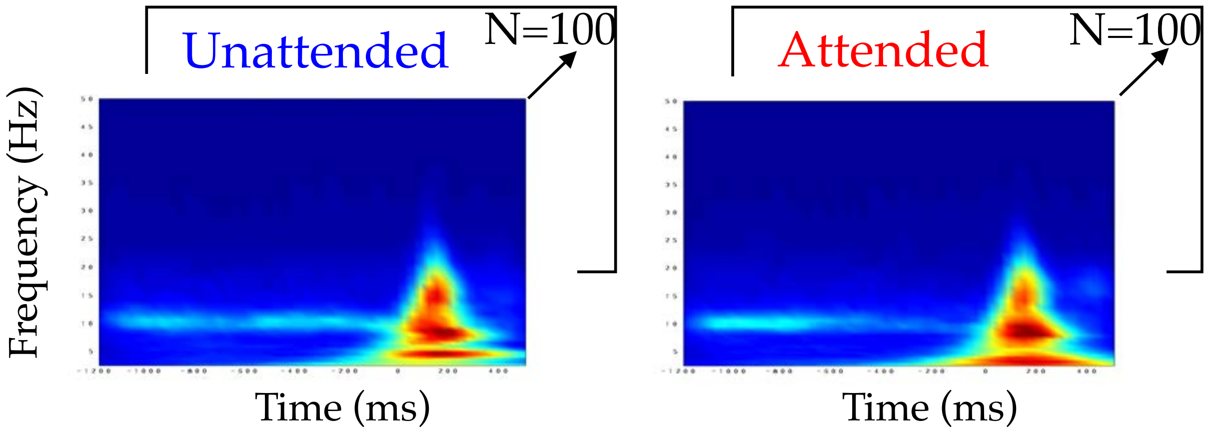


Why is that?

(1) Averaged waveforms, then made scalograms



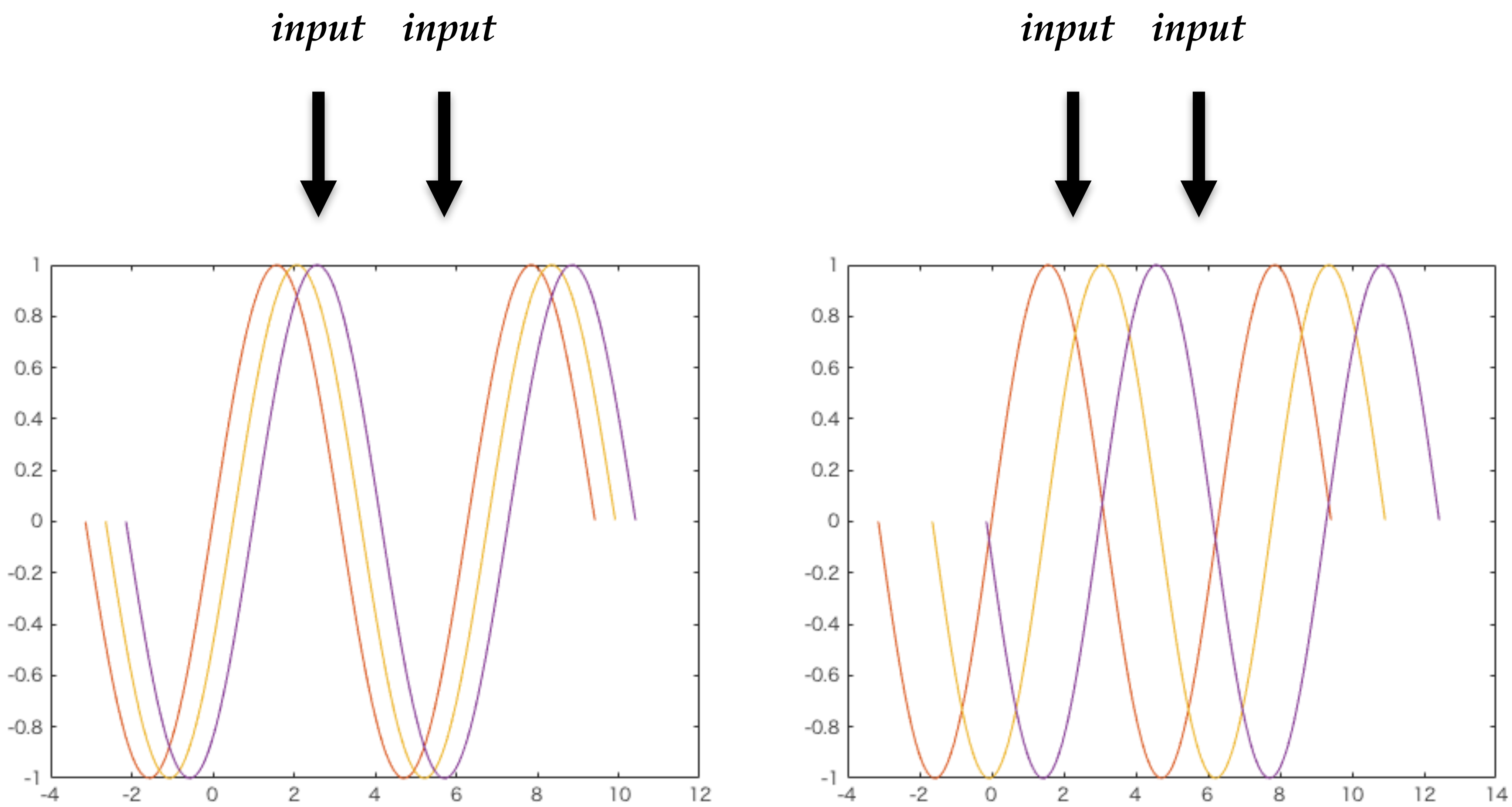
(2) Made single-sweep scalograms



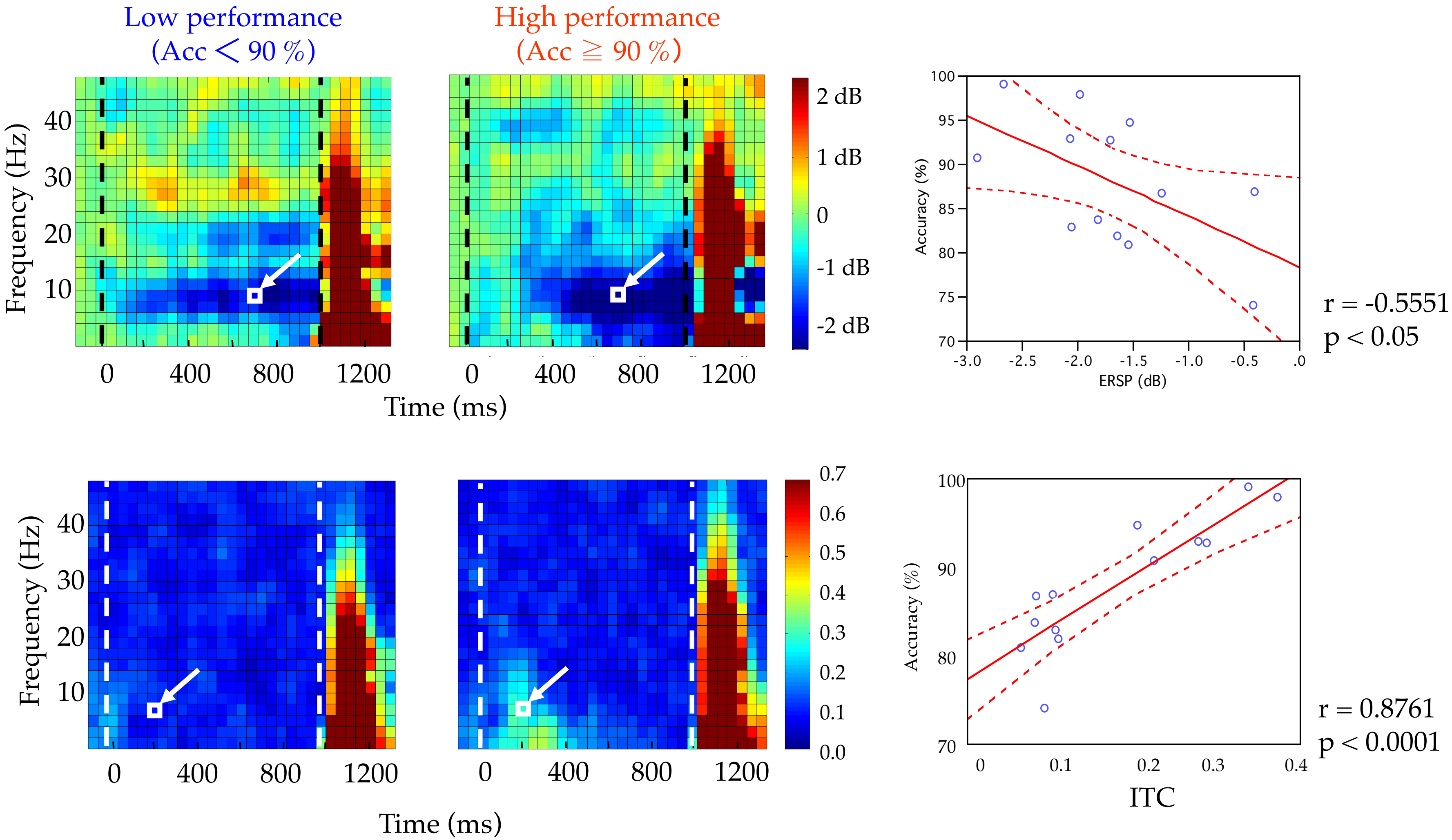
Why is that?

Because …

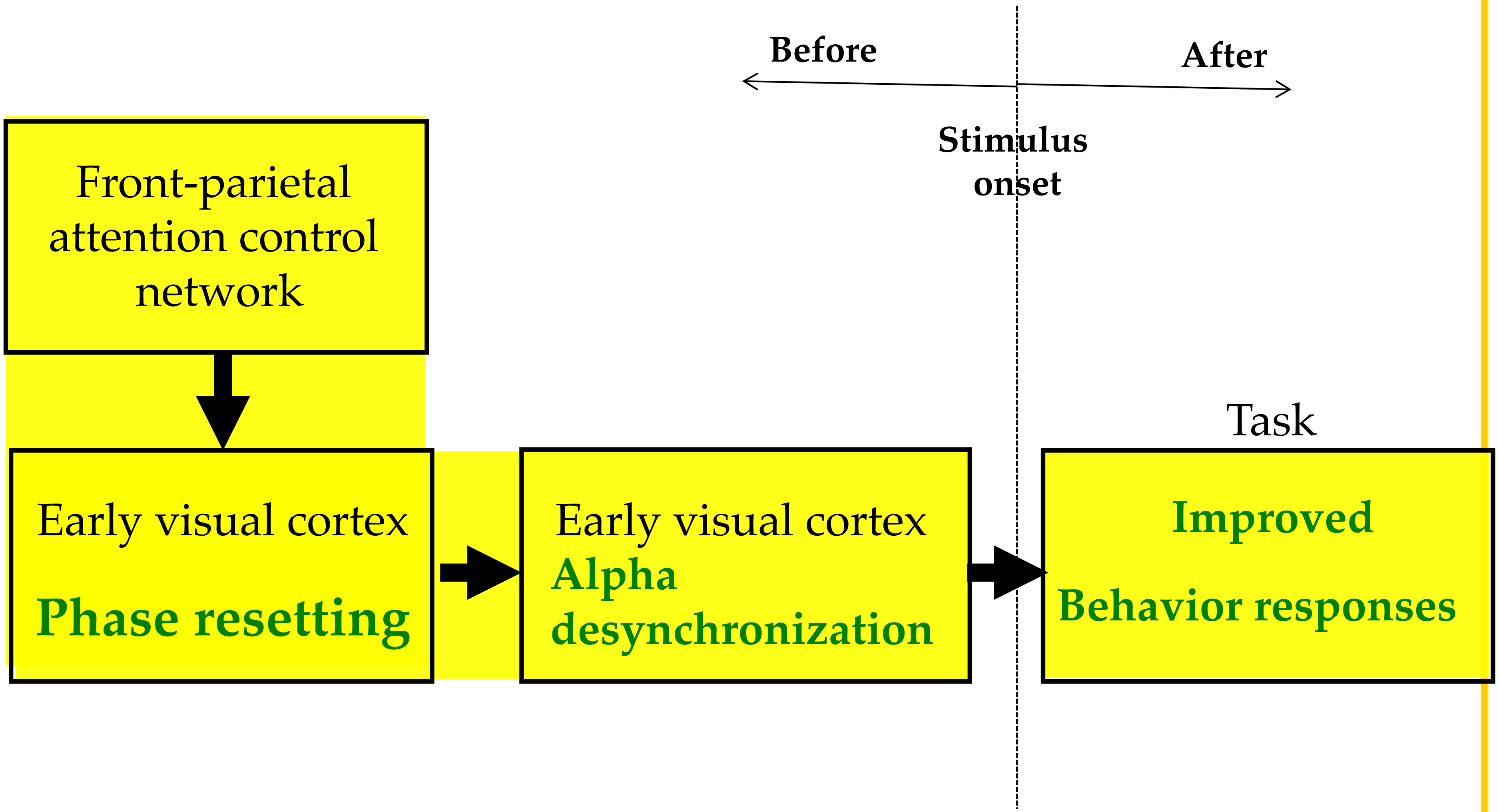
Attention affects
visual spontaneous activities
(phase not time-locked to trial start)


input
input
input
input

Attention and Performance



Proposed spatial attention control model

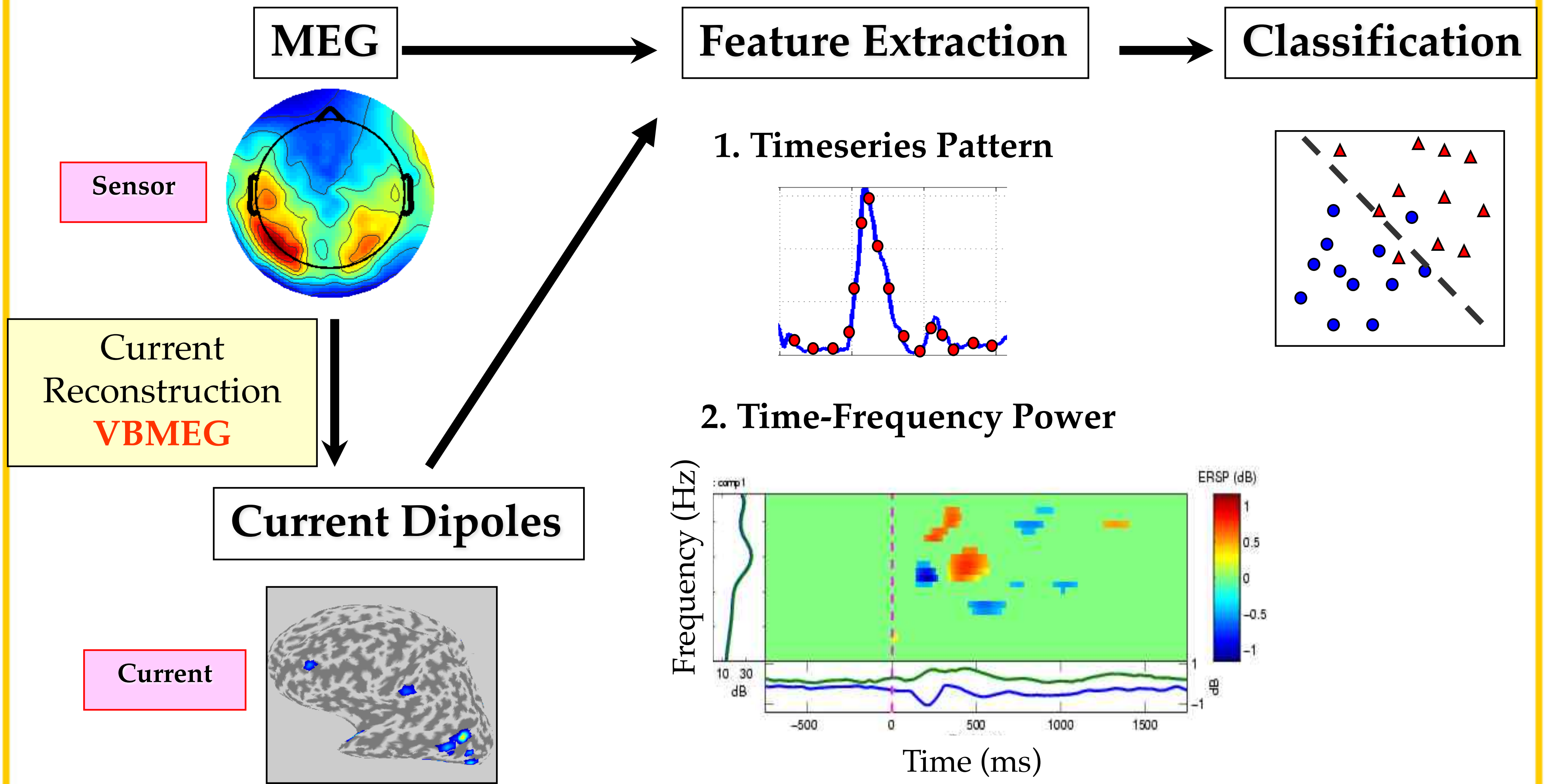


Predict attentional status from human brain activities

decoding

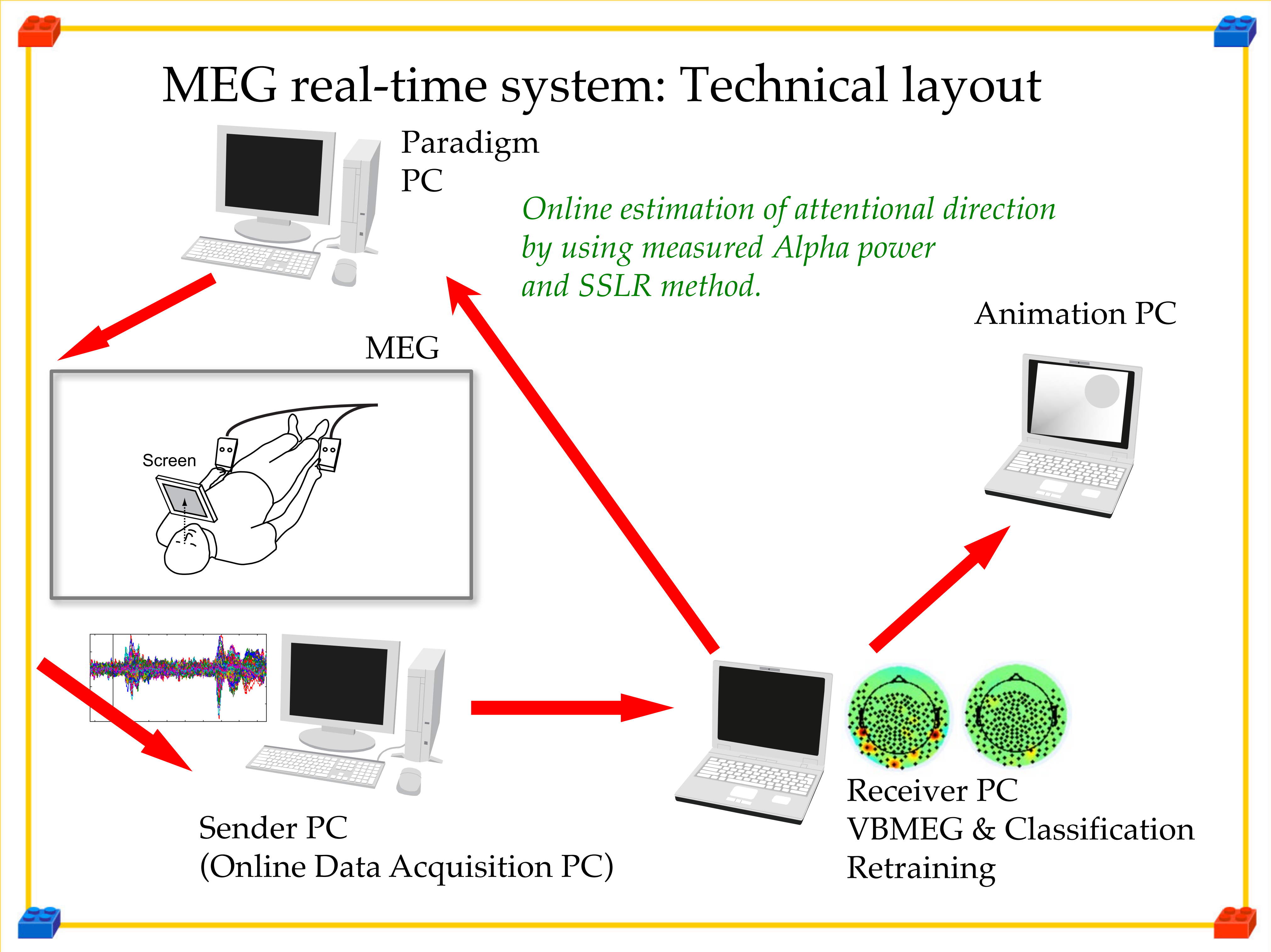
Predicting attentional status

Analysis Procedure

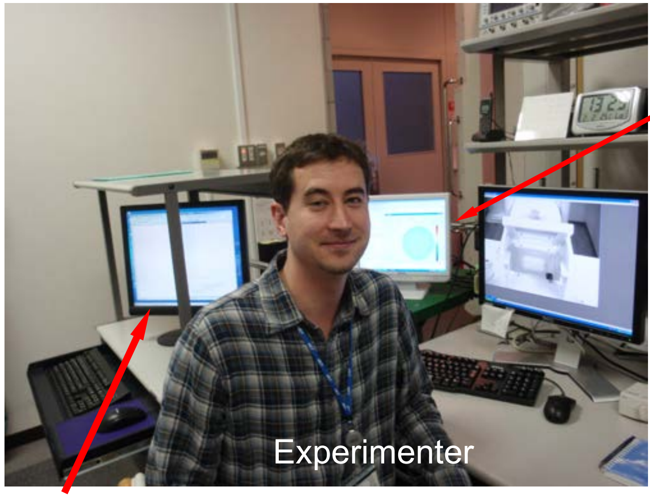


PREDICT ATTENTIONAL DIRECTION

ONLINE STUDY

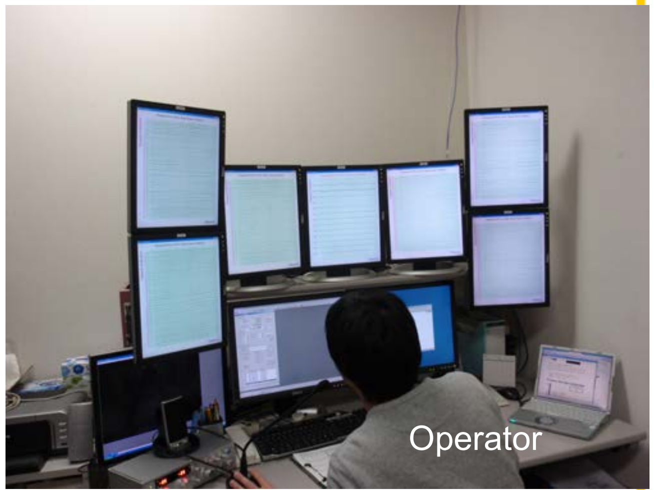

MEG real-time system: Technical layout
Paradigm PC
Online estimation of attentional direction by using measured Alpha power and SSLR method.
Animation PC
MEG
Screen
Sender PC
(Online Data Acquisition PC)
Receiver PC
VBMEG & Classification
Retraining

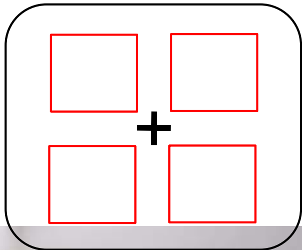
Online decoding of attentional direction



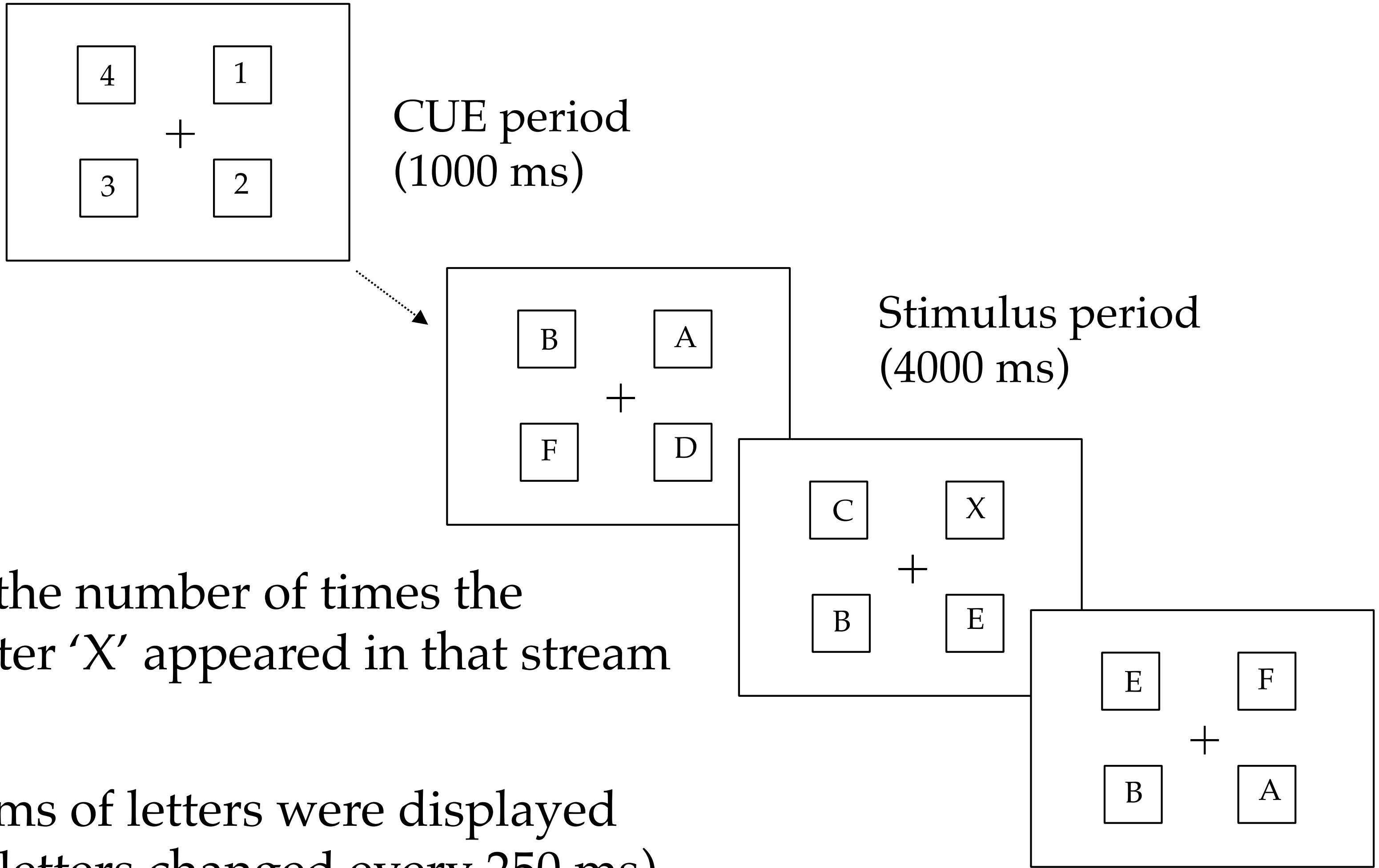
Paradigm PC
  Presenting stimuli
Receiver PC
  Classification

Sender PC
(Online Data Acquisition PC)





Online decoding of attentional direction

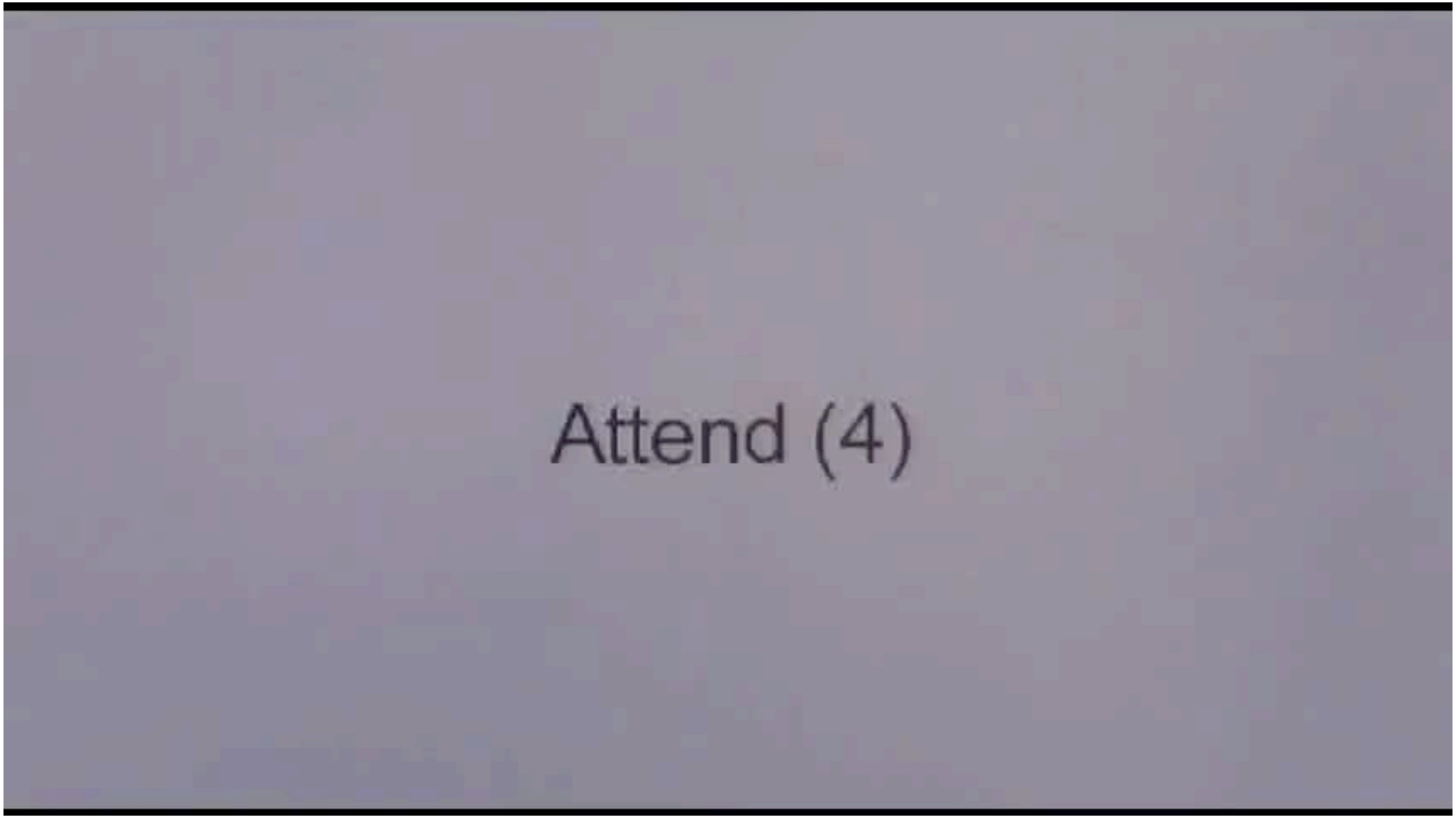


1. Task
Counted the number of times the target letter 'X' appeared in that stream

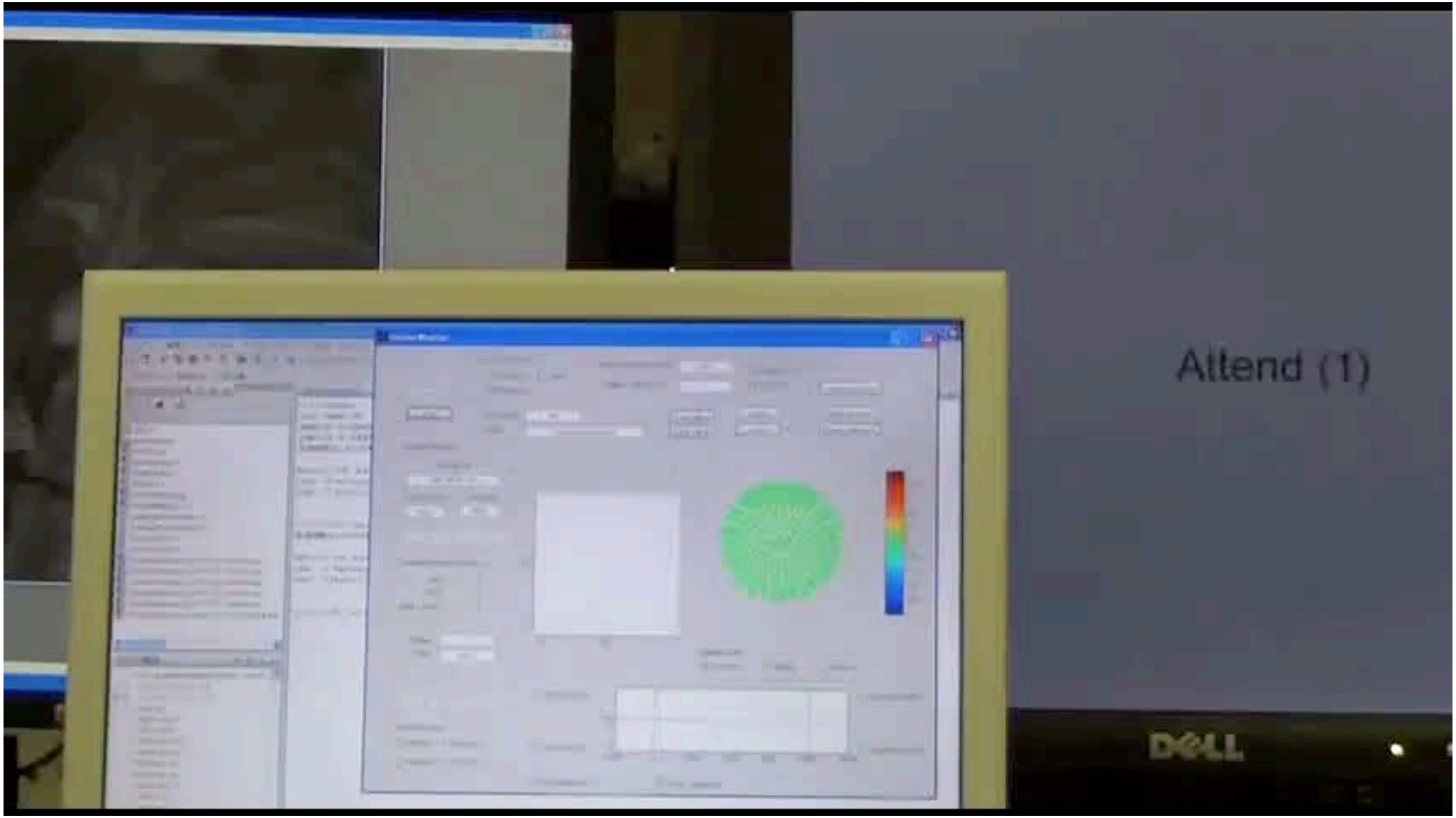
2. Stimuli
Four steams of letters were displayed for 4 sec (letters changed every 250 ms)
A, B, C, D, E, F, G, H, X

3. Real time Decoding

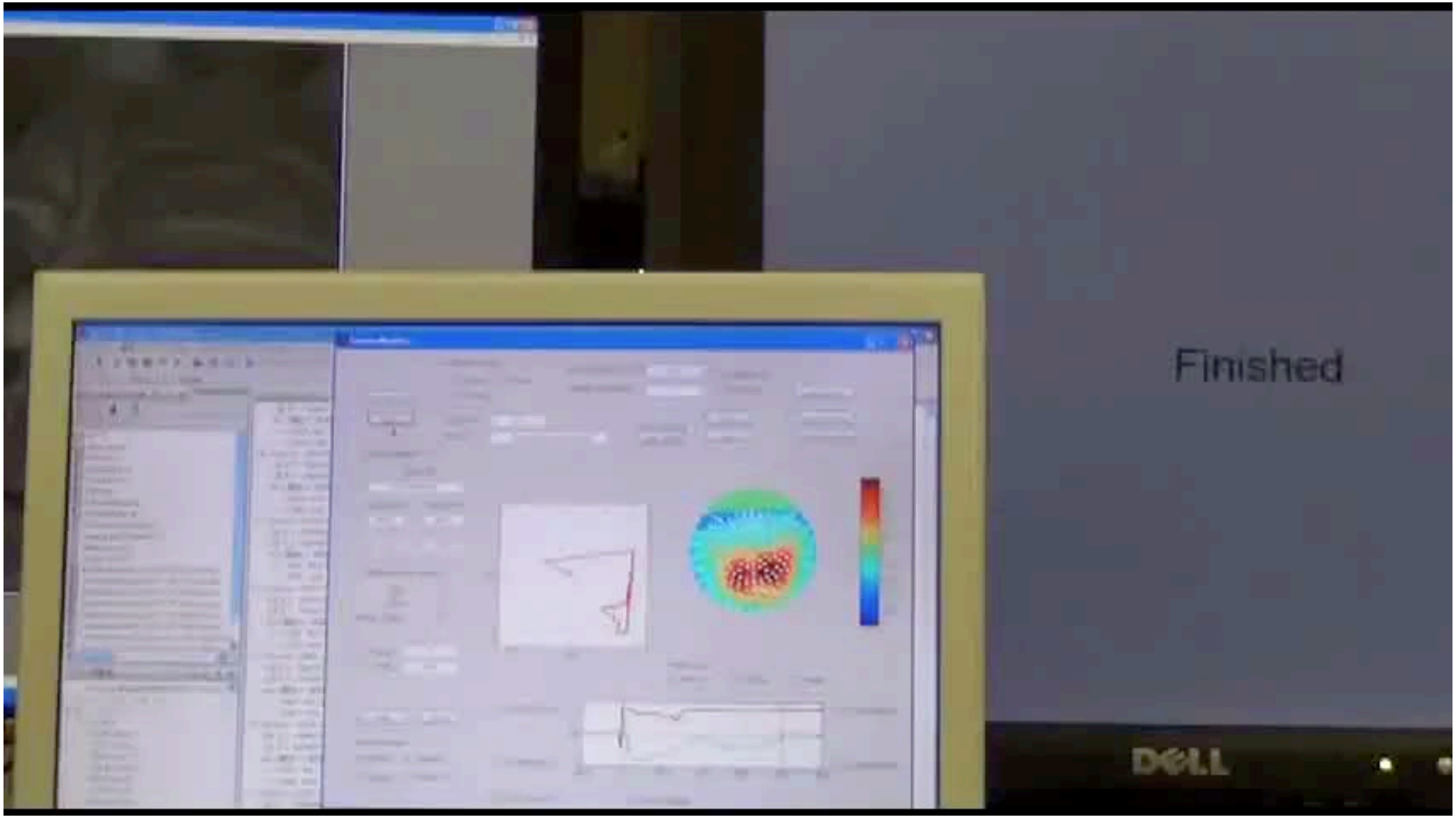
ATTEND TO (4)



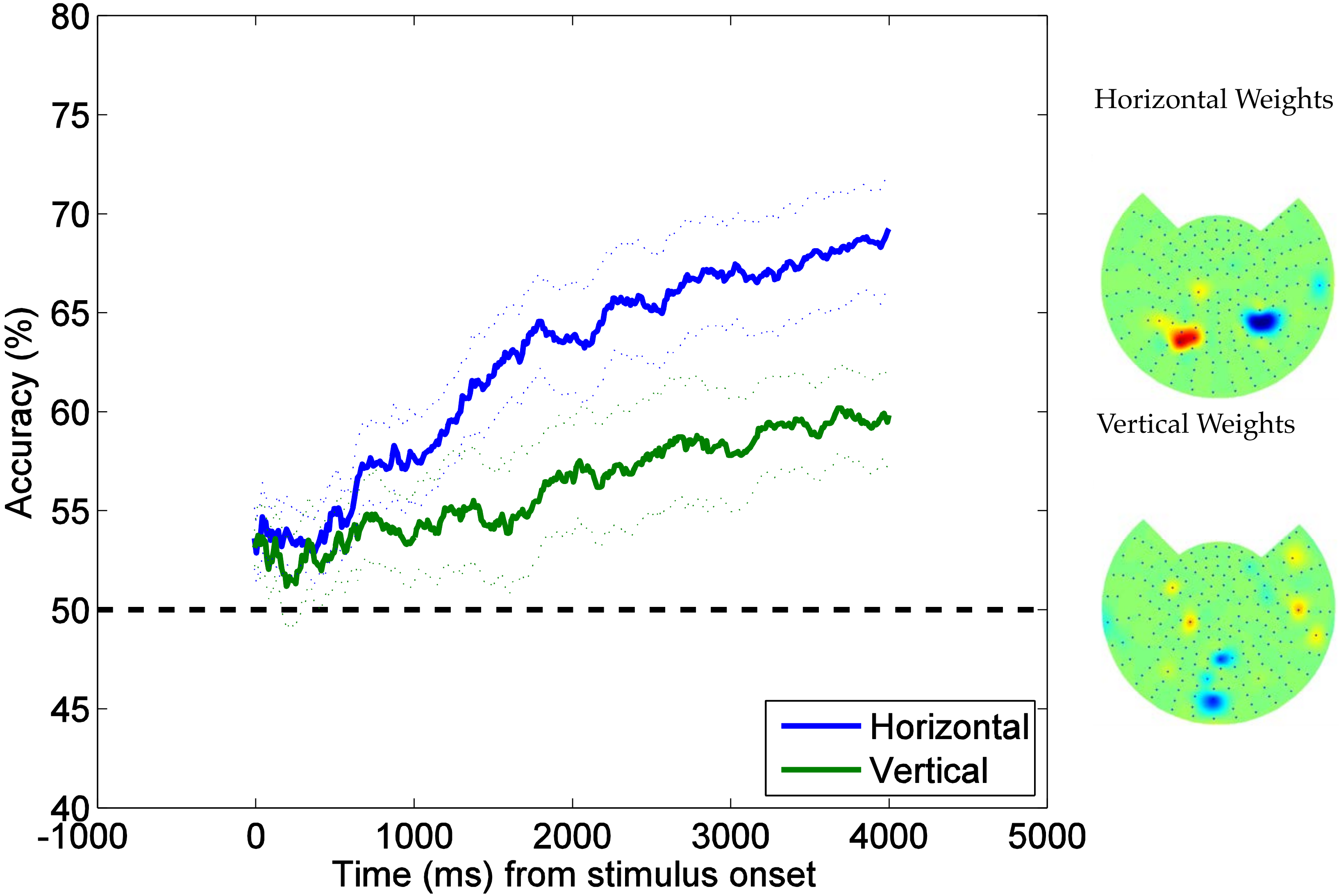
Attend to (1)



Which number did the subject decide to attend to?



Online decoding of attentional direction

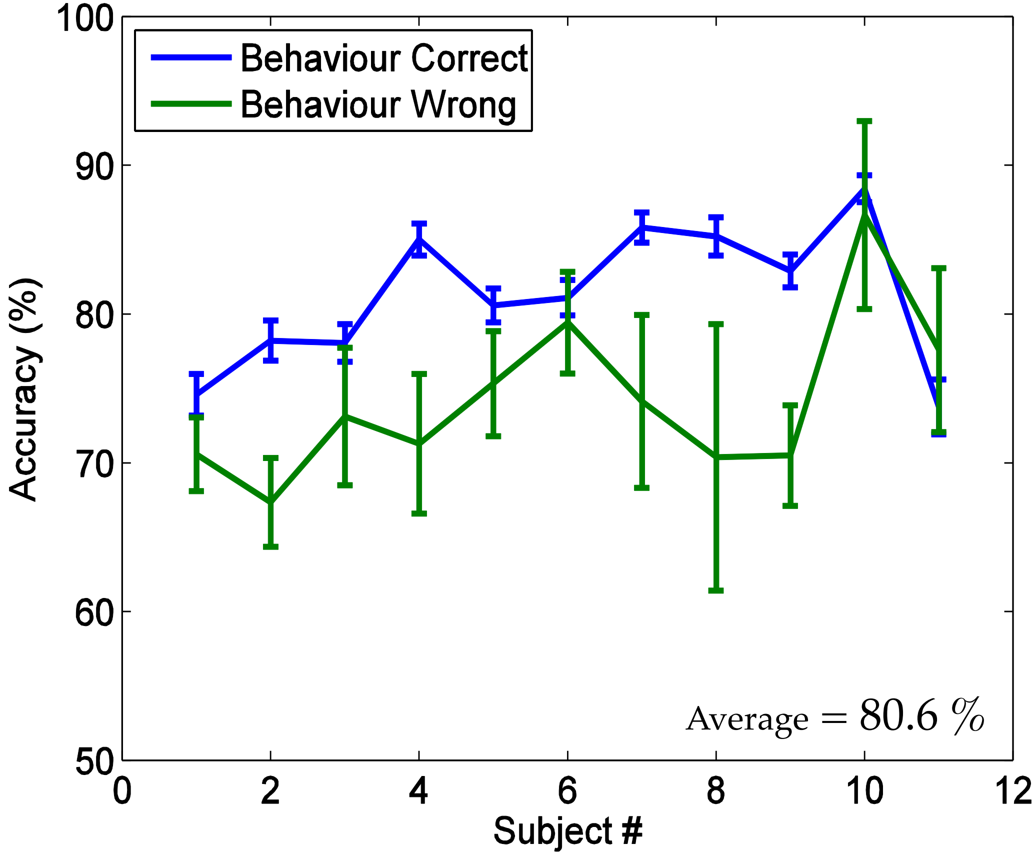


Average performance = 43% (chance = 25%,n=12)

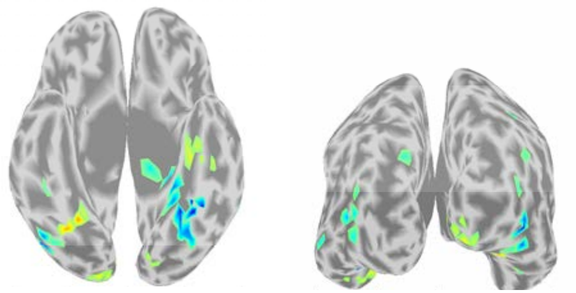
Online decoding of attentional direction

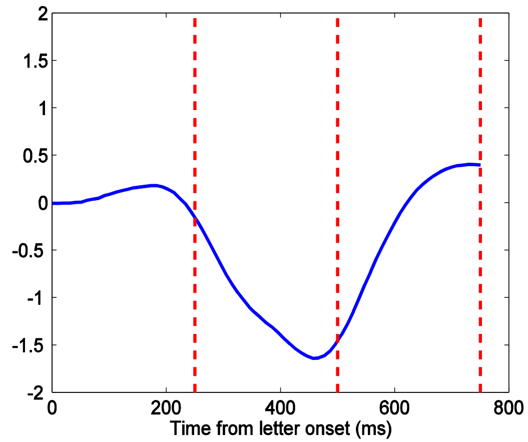
Target letter decoding

Cortical level



Weights





One decoder for all directions.

Performance was 7.0% better on trials which the subject responded correctly than on incorrect trials ($p < 0.005$).

Online decoding of attentional direction

Attentional direction can be predicted in real-time using MEG [spatial attention].

Target/Distractor classification is also possible with high accuracy [feature/temporal attention].

Spatial attention may filter visual information in the early stage. Target detection may occur in the higher cortical areas.

Consciousness and …

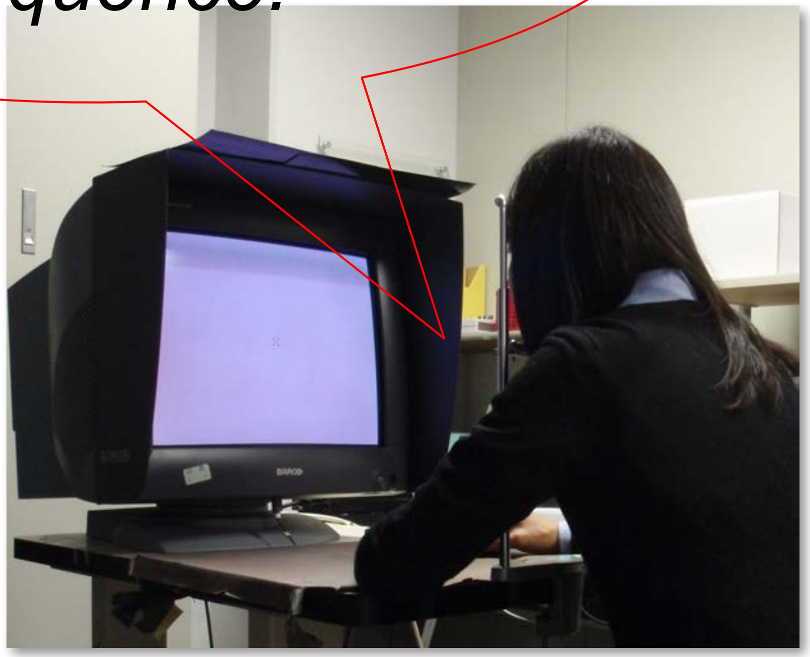
Readiness

When you are ready ...

Psychophysical experiments

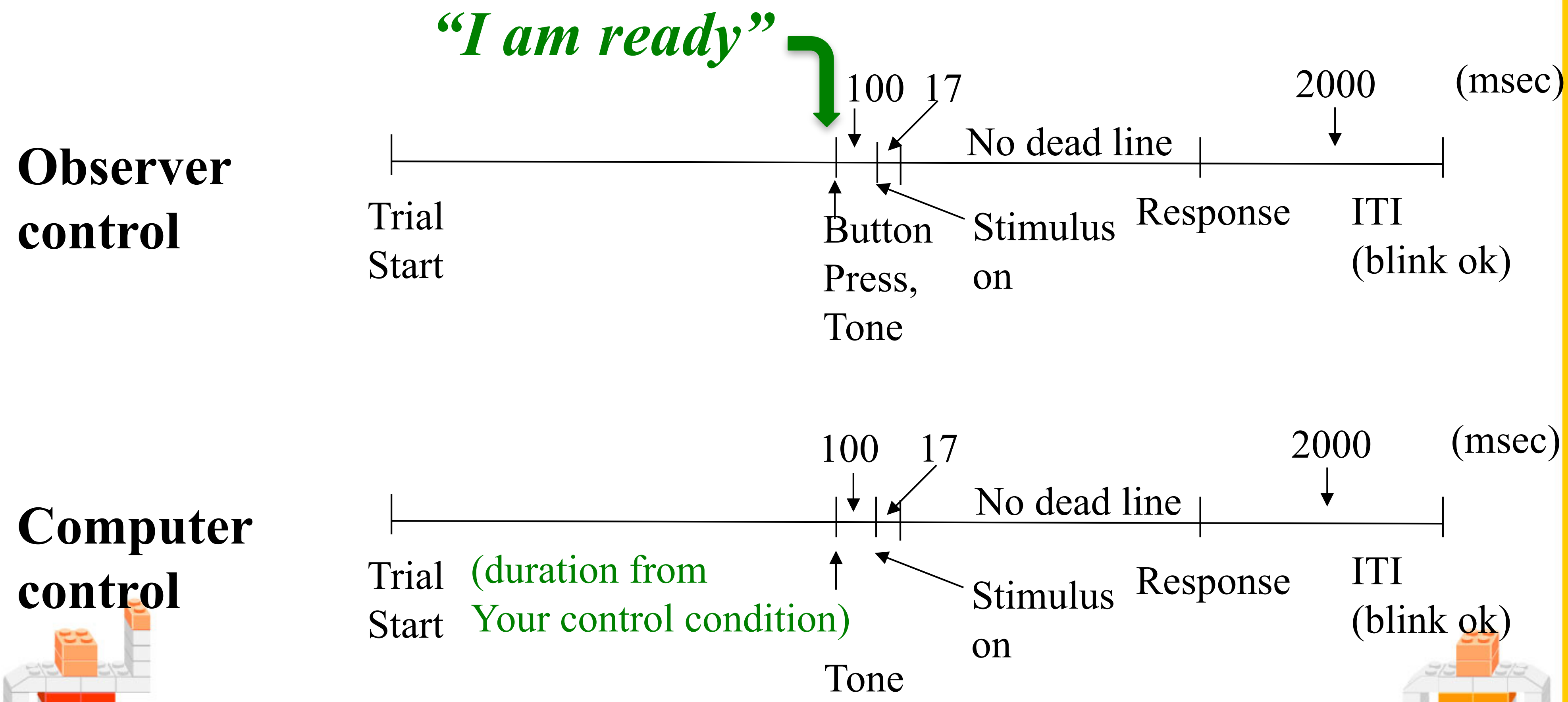
Can you tell when you are ready?

When 'you are ready', press a button to initiate a trial sequence.



Can you tell when you are ready?

Methods



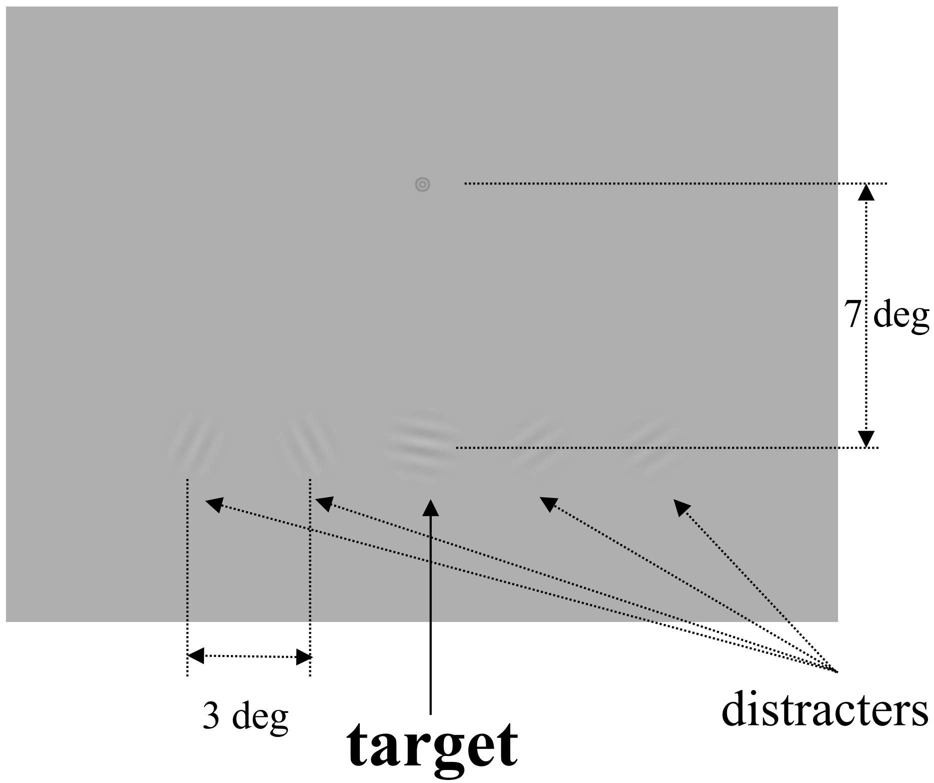
Can you tell when you are ready?

Stimuli

Method of constant stimuli

Target

Contrast (ranges: 5-70%, 10 steps)
Spatial frequency = 2 c/deg
Gabor window size SD = 0.5 deg
Orientation ±5 deg
from horizontal meridian



Distractors

same as target, except orientation
randomly chosen from 0-360 deg, contrast = 0.5

Background color

CIE (0.31, 0.32), Luminance = 40 cd/m^2

Can you tell when you are ready?

Procedure

Practice
4 days experiments (32 blocks (30 trials))
-> Total of 48 measures for each contrast

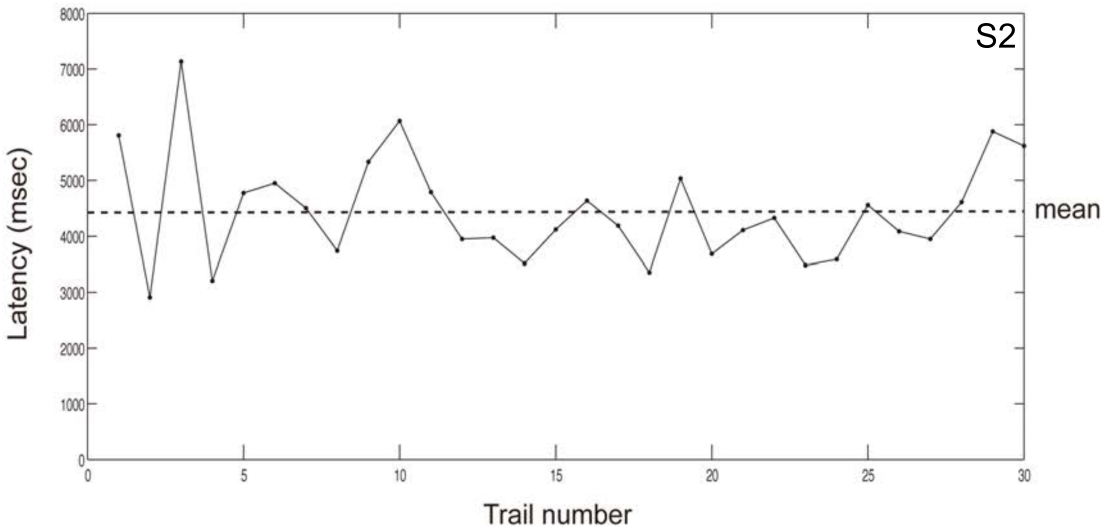
Eye movements were monitored (EyeLinkII)

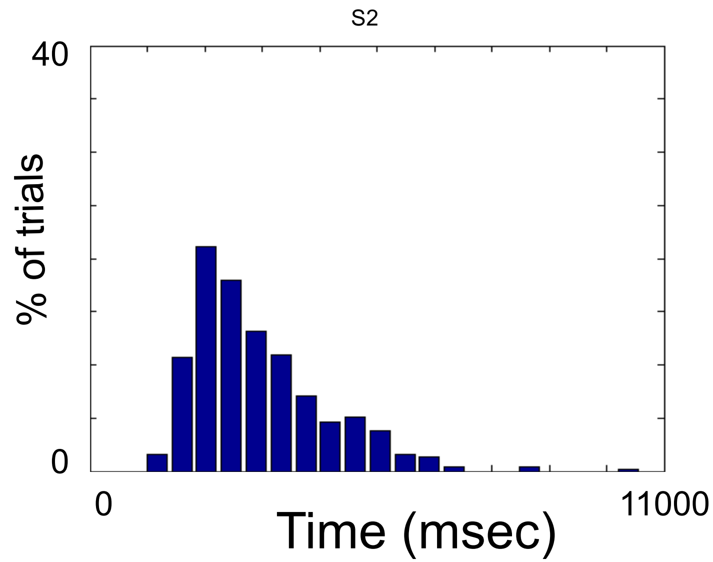
demo

Can you tell when you are ready?

YES!

But, time varied from trial to trial.

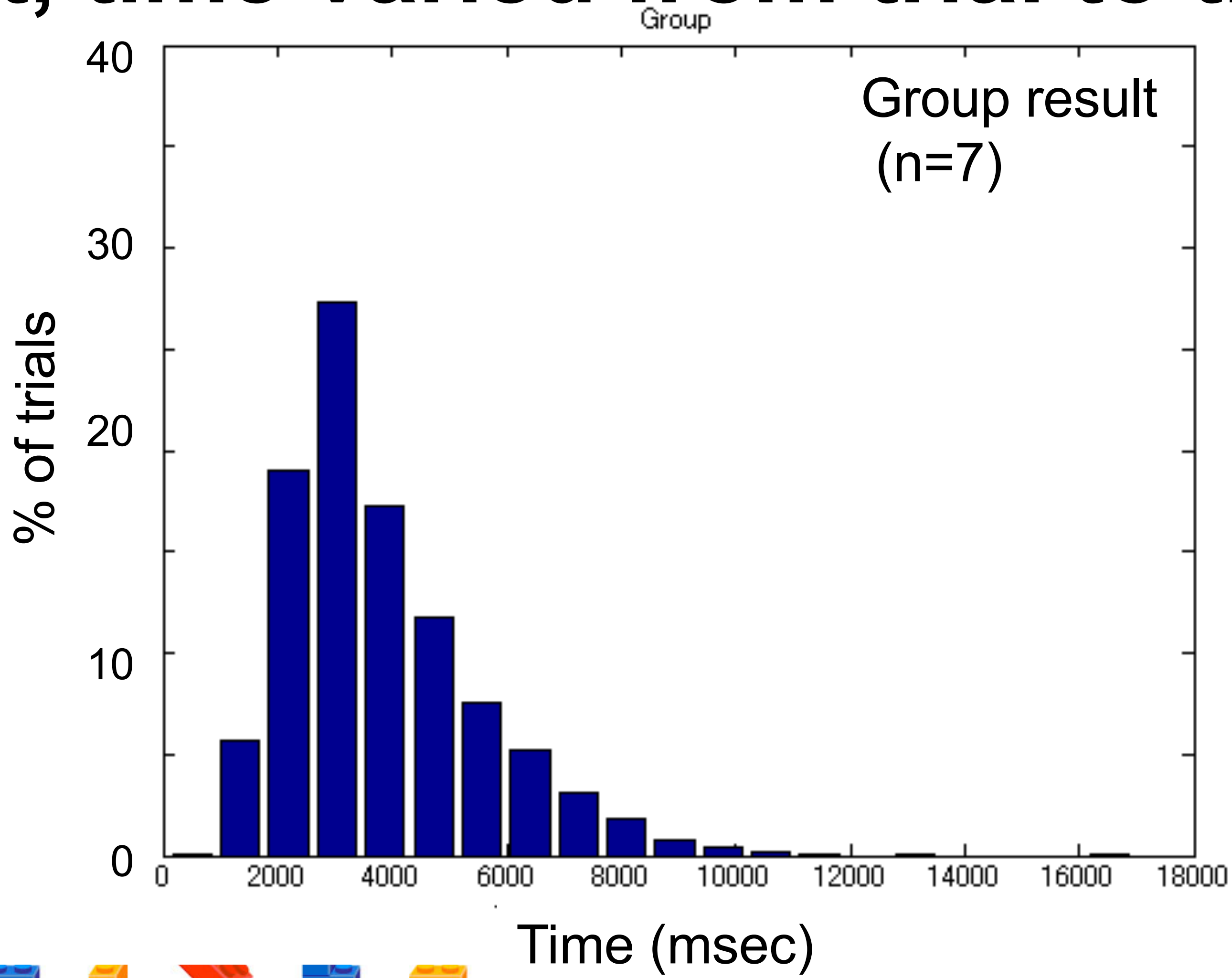




Can you tell when you are ready?

YES!

But, time varied from trial to trial.



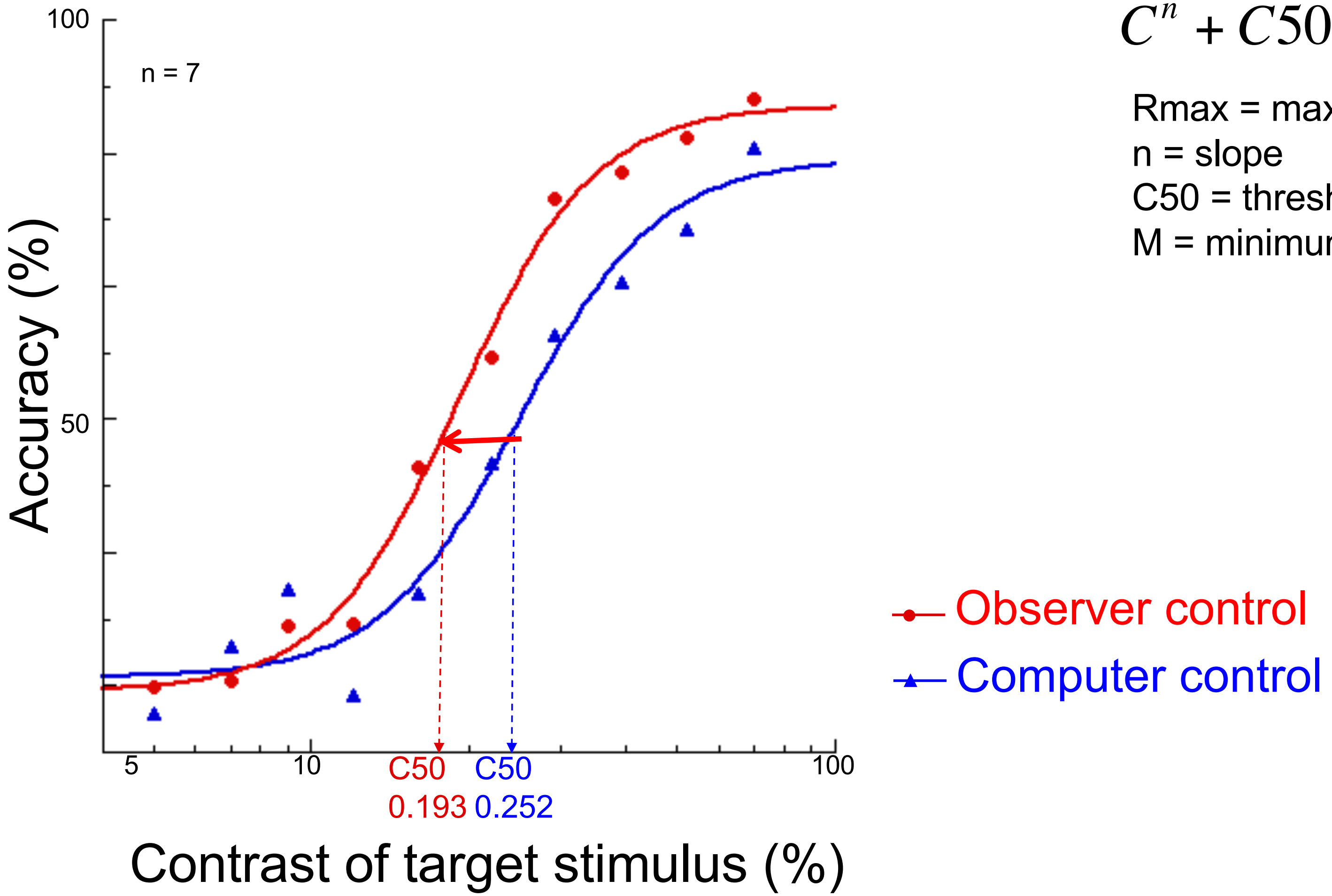
When you are ready, is your performance better?

YES!

Fitting with Contrast Response Function

$$\text{Response} = \frac{R_{max} \times C^n}{C^n + C50^n} + \text{M}$$

Rmax = maximum value
n = slope
C50 = threshold
M = minimum value



When you are ready, is your performance better?

Fitting with Contrast Response Function

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Rmax = maximum value
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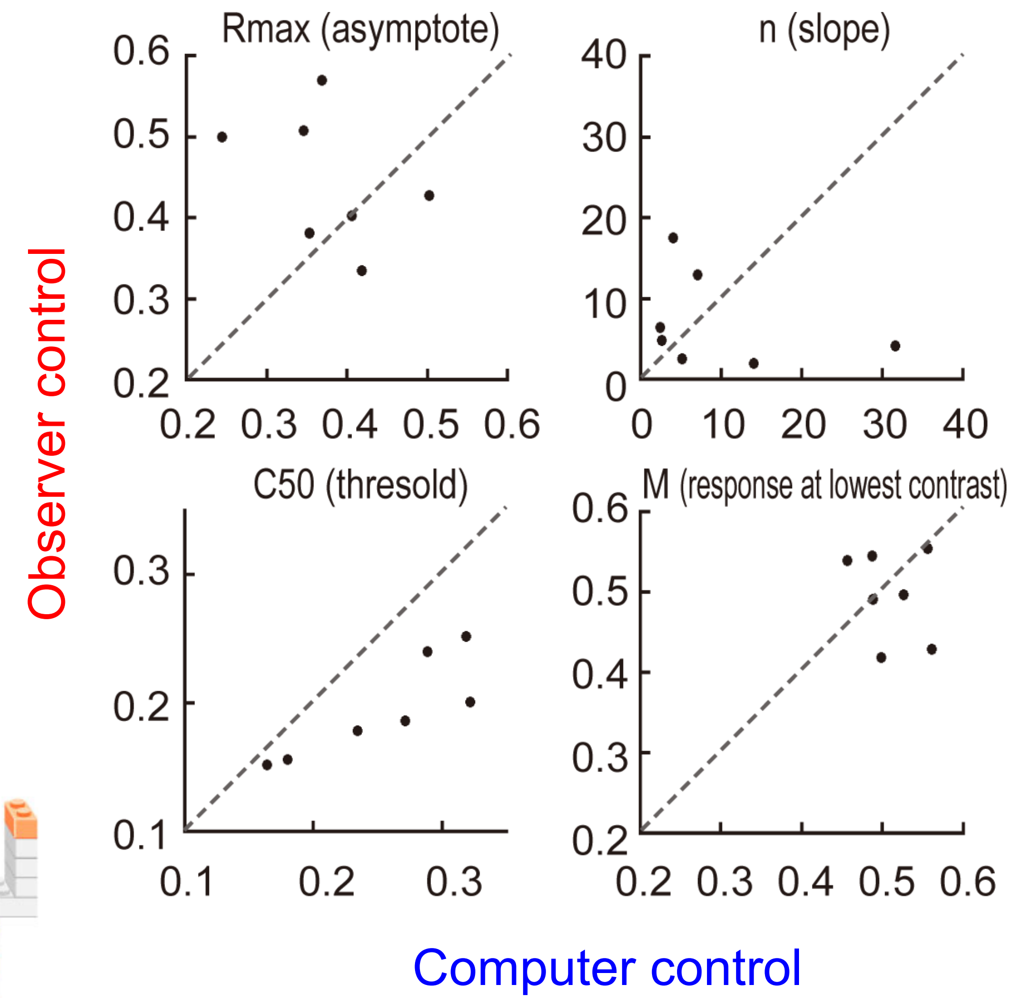
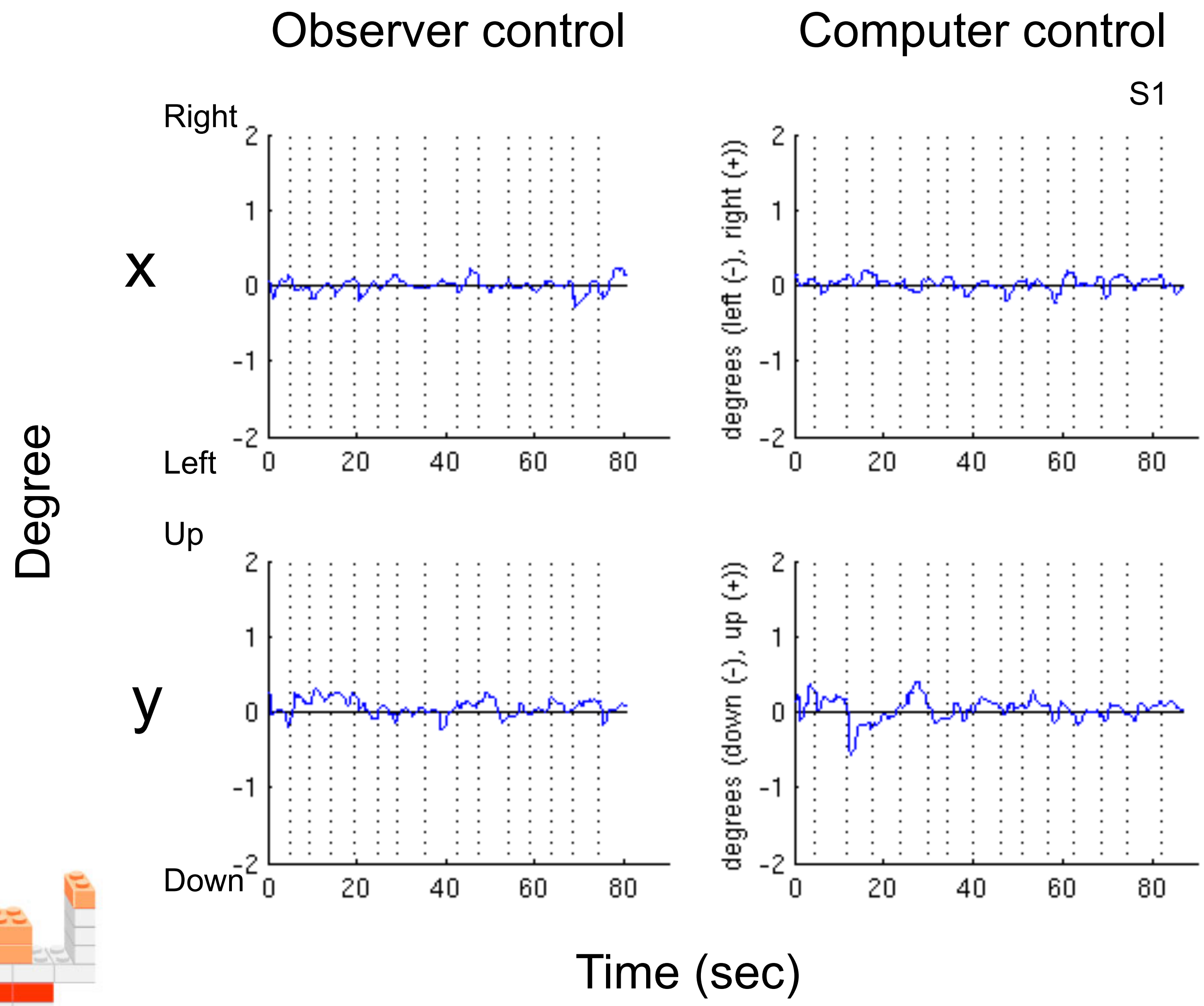


Only threshold (C50) was significantly differed between conditions.
paired t-test (n=7)

Eye movements

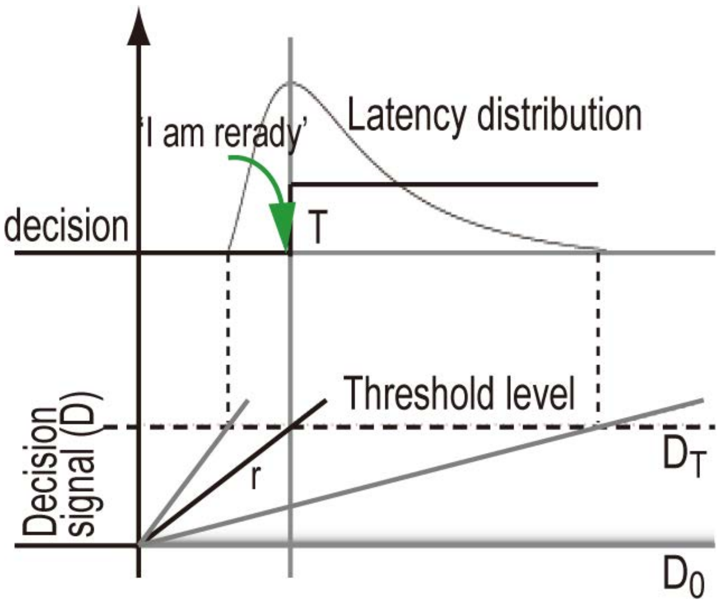


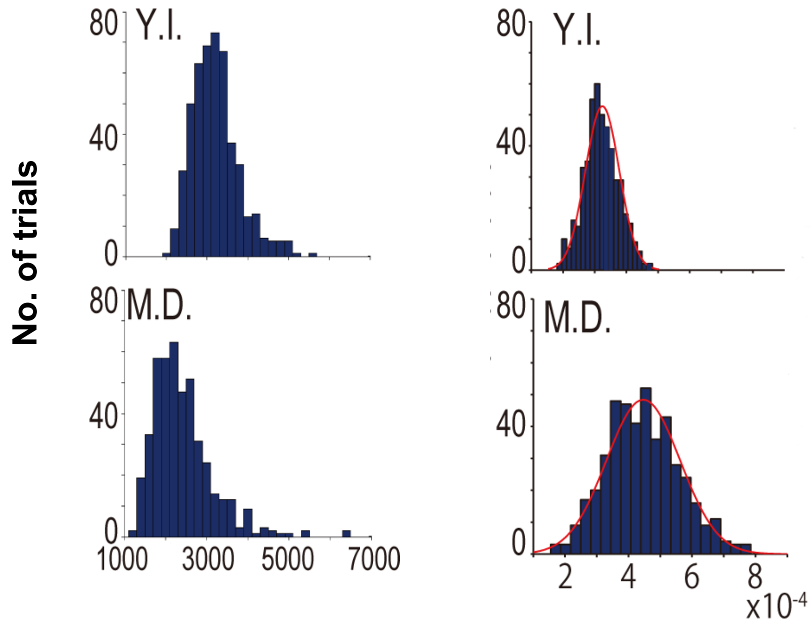
No systematic eye movements were observed in both Observer control and Computer control conditions. For each subject,and for most of trials, eye movements were less than ±0.5degrees.

-> Observed differences in threshold changes were not due to subjects' eye movements.

What kind of mechanism underlying this decision?

Linear rise-to-threshold model
The LATER model (Carpenter & Williams, 1995)
(The Linear Approach to Threshold with Ergodic Rate model)

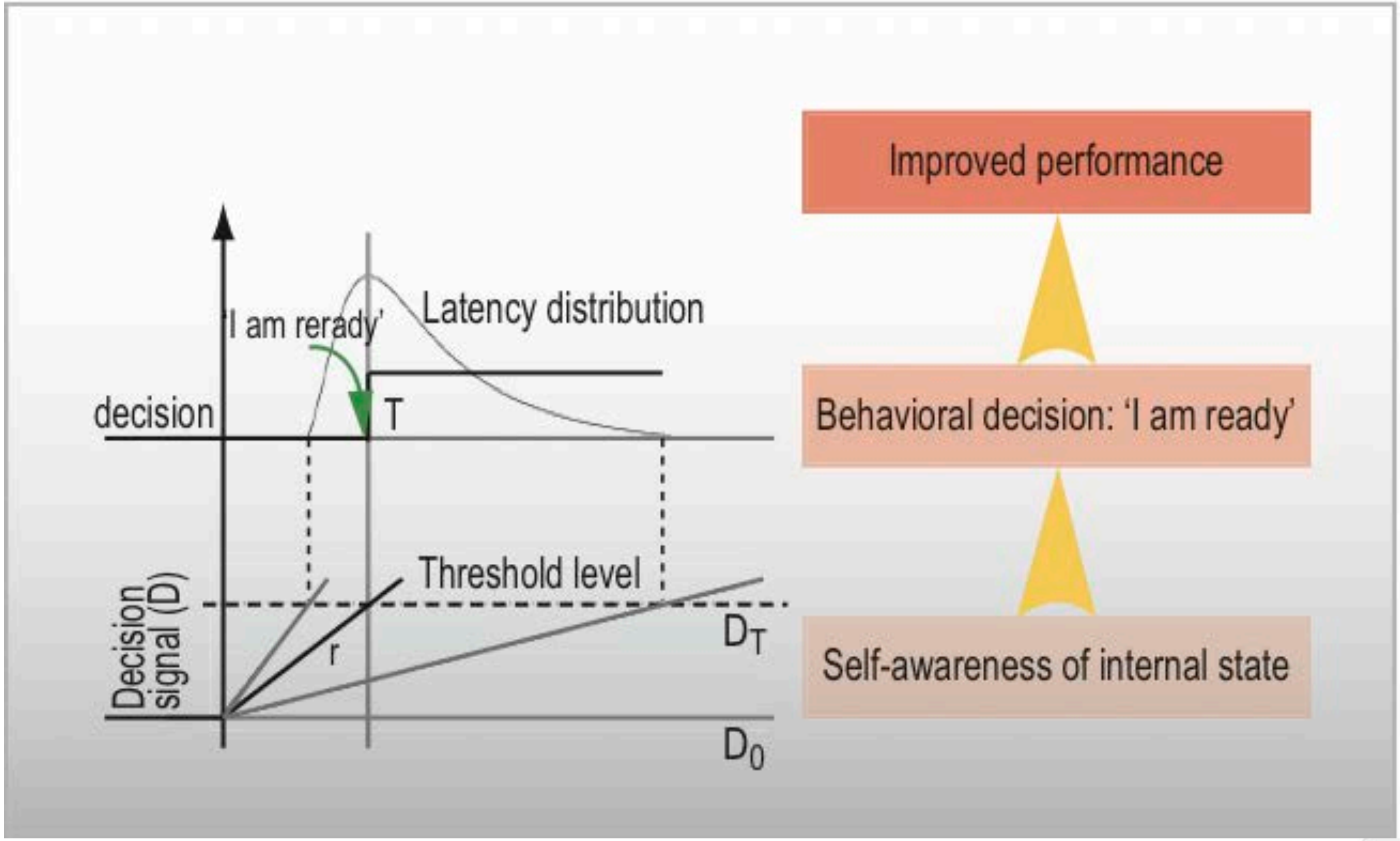




Latency (ms)

1/Latency (ms)

What kind of mechanism underlying this decision?



Summary of Psychophysics

1. No one had difficulty to press a button when “he/she was ready” to see a target.

-> *Humans can tell “I am ready”.*

2. After psychophysical experiments, all subjects reported that a target was easier to see in the condition of “Observer control” compare to “Computer control.”

Summary of Psychophysics

3. When humans feel “I am ready”, visual sensitivity is significantly better.

4. The obtained threshold changes were not due to eye movements.

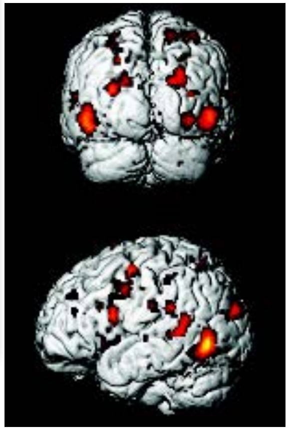
5. The delay times for judging attentional status is well explained by a linear rise-to-threshold model.

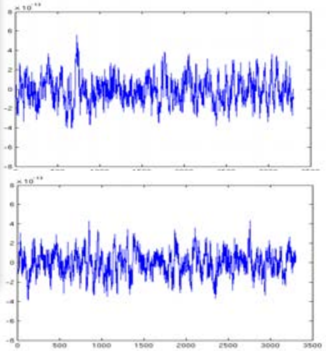
Brain imaging studies

Which brain areas have important roles for this mechanism?

To investigate neural basis of self-monitoring internal status for the purpose of enhancing behavior performance, we conducted fMRI and MEG experiments.

Which brain areas have important roles for this mechanism?



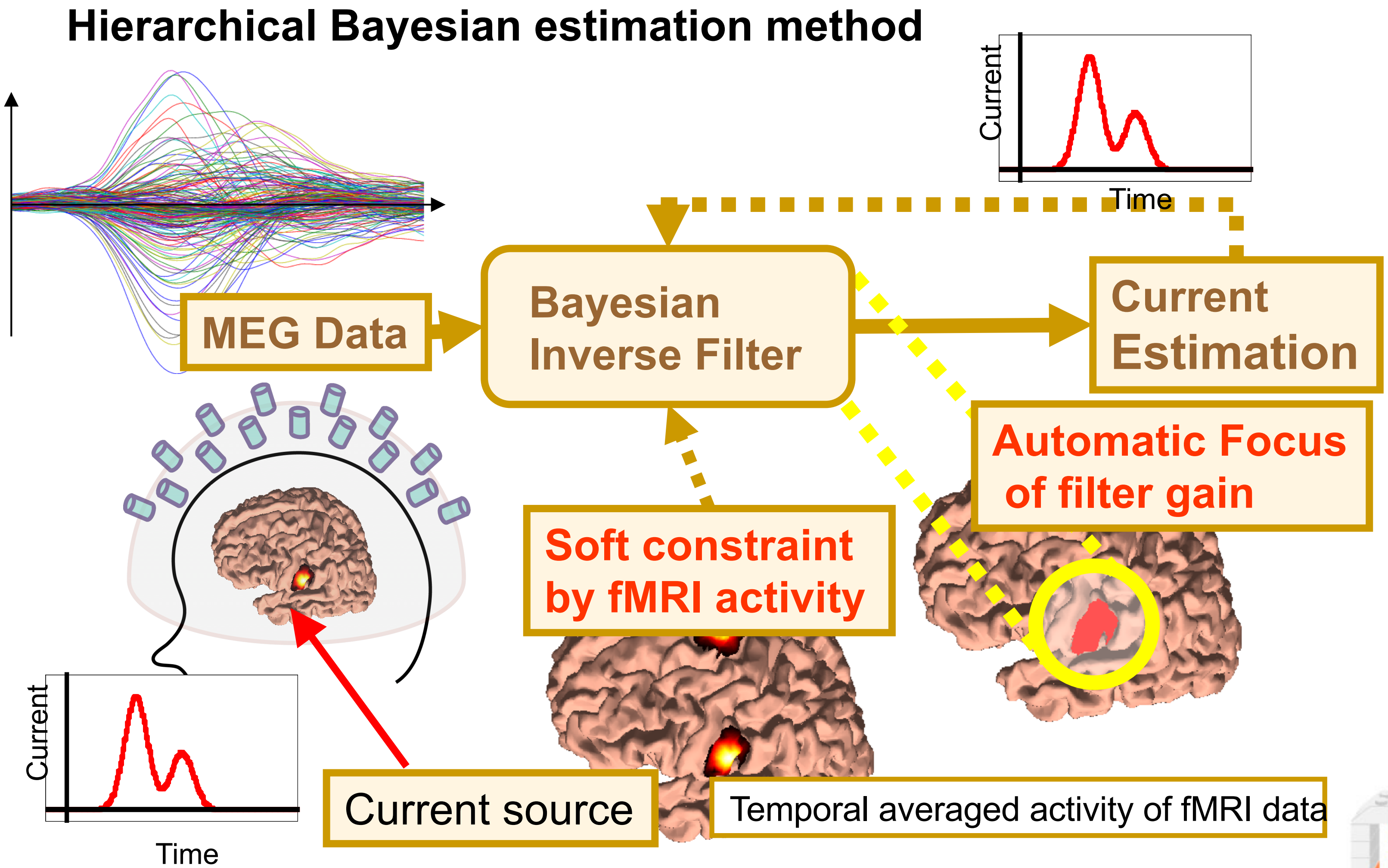


ATR Brain imaging center

fMRI + MEG

Good resolutions in both Space (mm) and Time (msec)

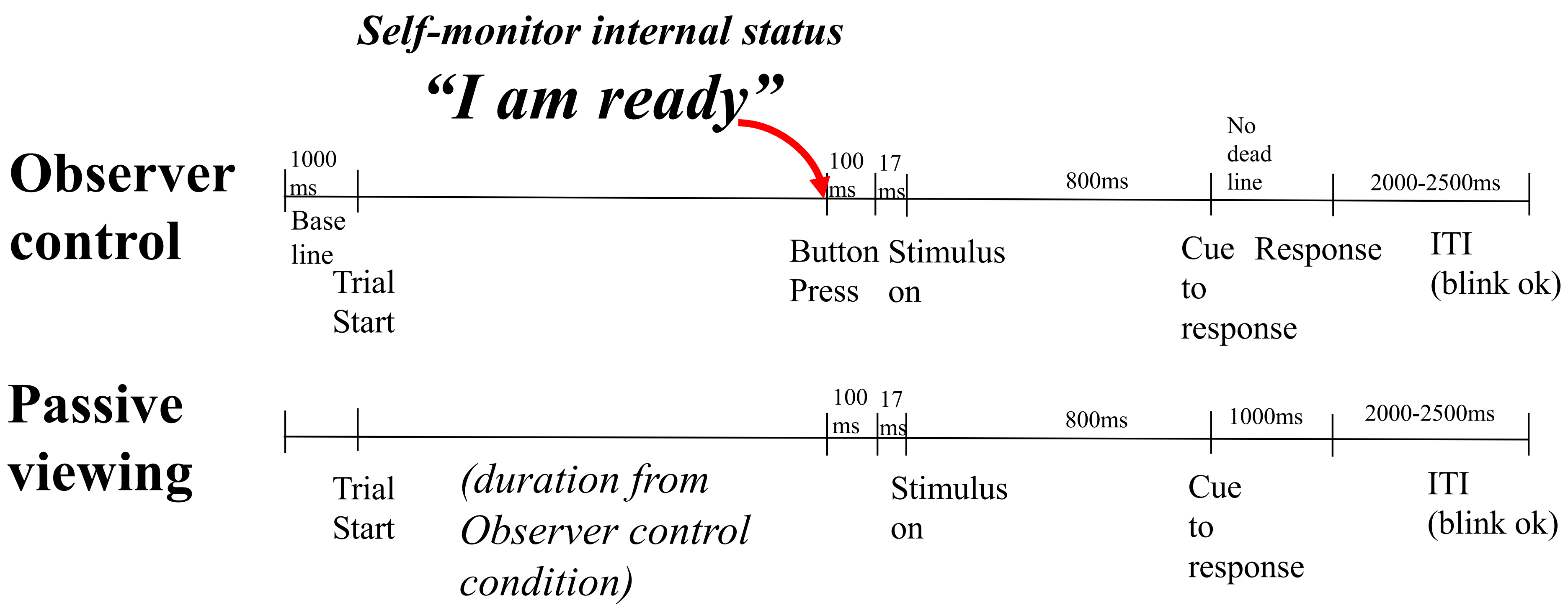
Which brain areas have important roles for this mechanism?



M. Sato et. al. Hierarchical Bayesian estimation for MEG inverse problem. *NeuroImage, 23, 806-826 (2004)*

Which brain areas have important roles for this mechanism?

Methods



Which brain areas have important roles for this mechanism?

Stimuli

Same as the behavior experiments.

Procedure

MEG

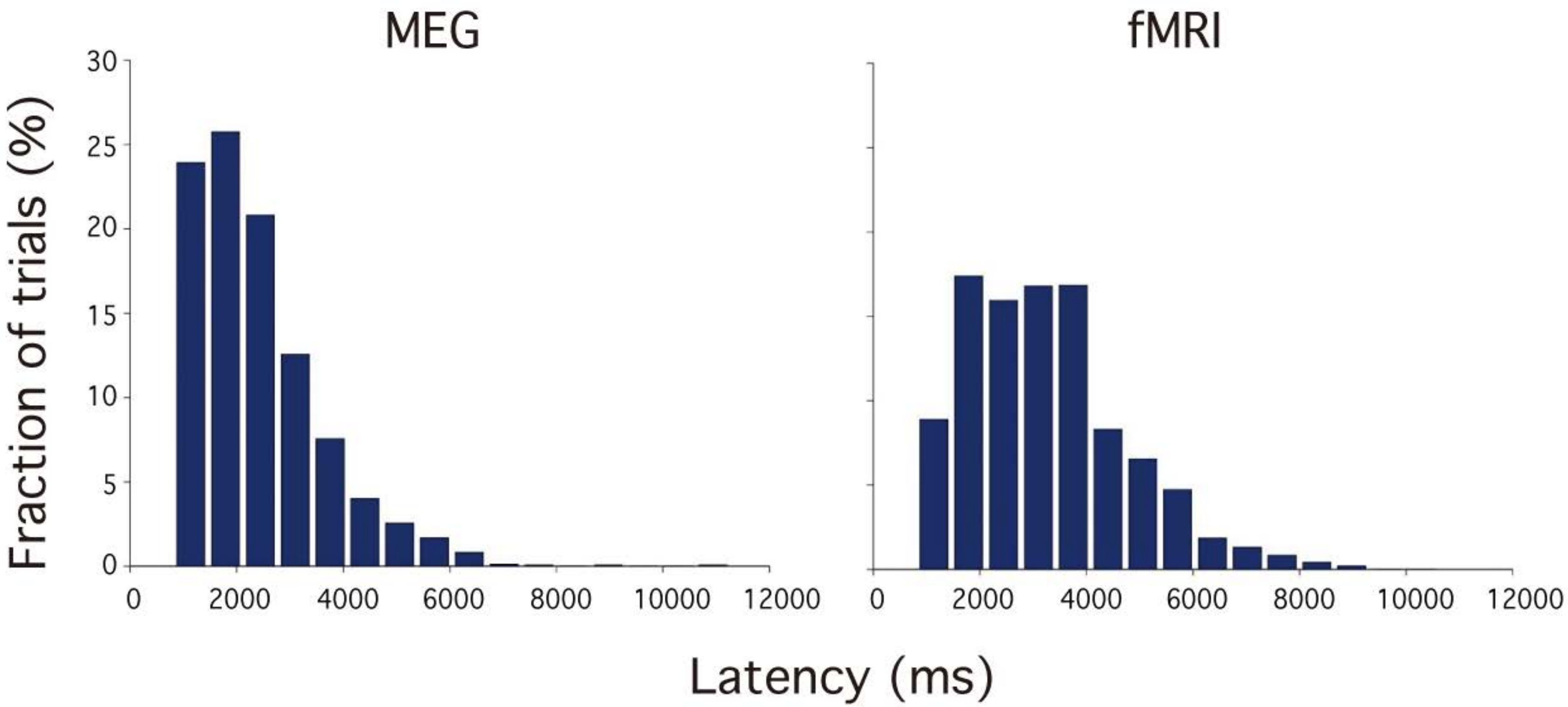
Two conditions: Observer control and Passive viewing
40 trials/block, 2 blocks/session
4 sessions for each subject (160 trials for each conditions)
Eye movements were monitored by EOG

fMRI

Three conditions: Observer control, Passive viewing and Rest
Blocked design
    6 trials/block, 6 blocks/1 session
10 sessions (160 trials for each conditions)

Which brain areas have important roles for this mechanism?

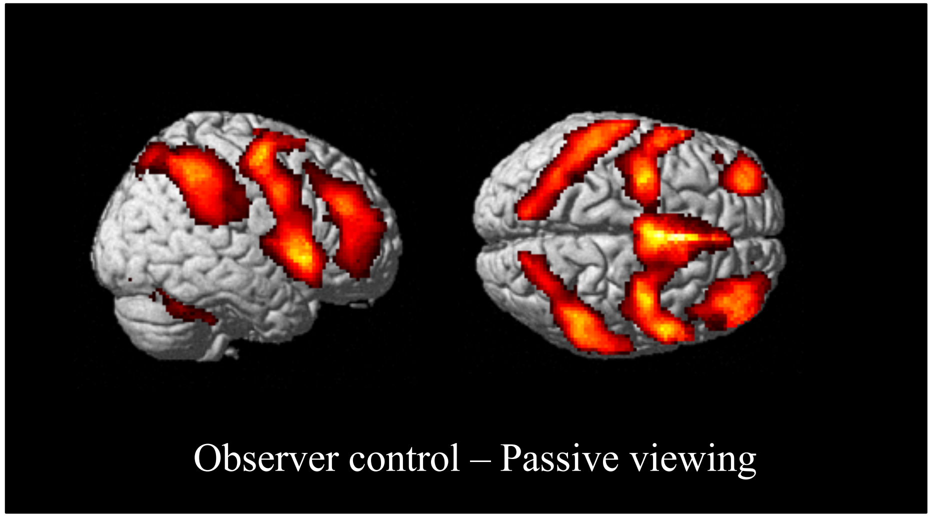
Durations need for “I am ready”



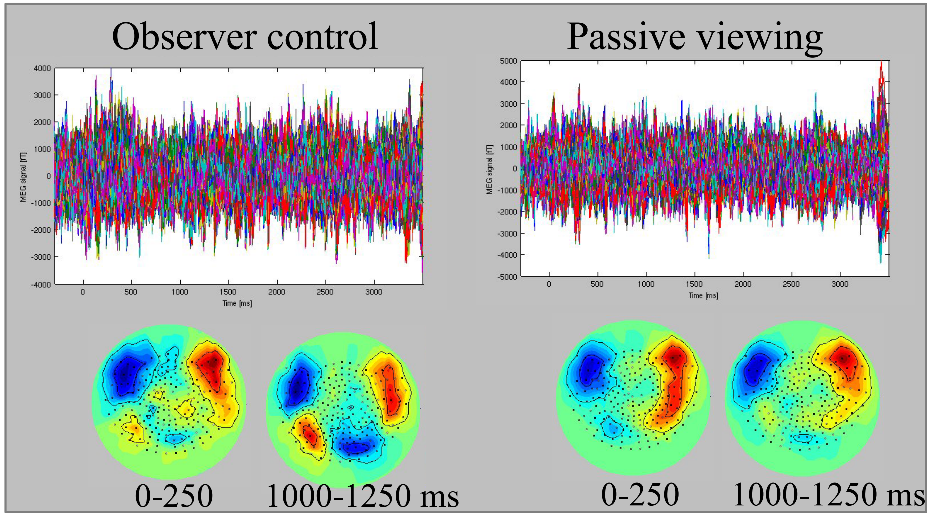
(n=10)

Which brain areas have important roles for this mechanism?

fMRI

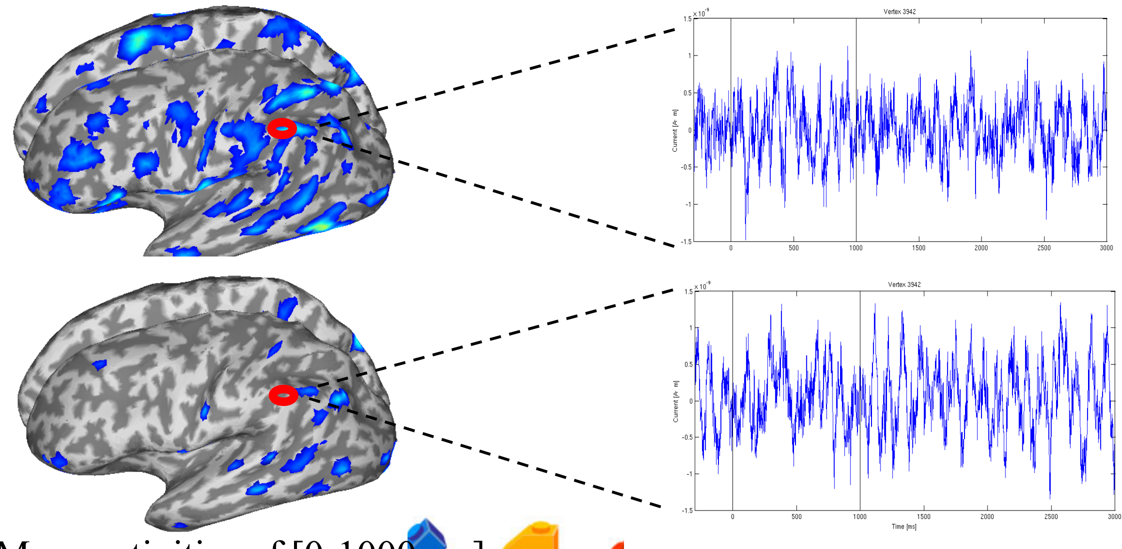


MEG



Observer control

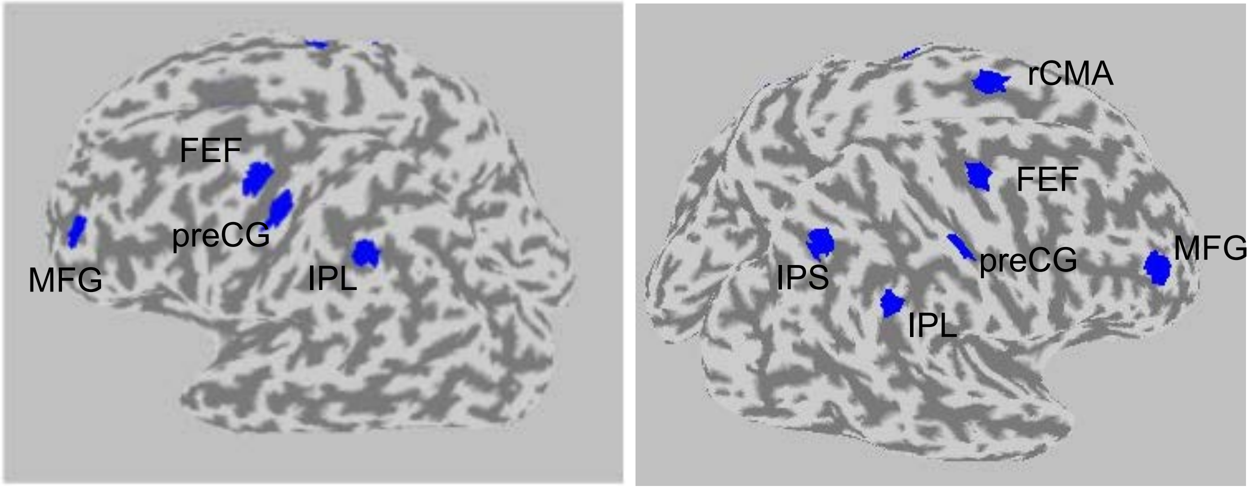
Passive viewing



Mean activities of [0-1000 ms]

Which brain areas have important roles for this mechanism?

10 ROIs

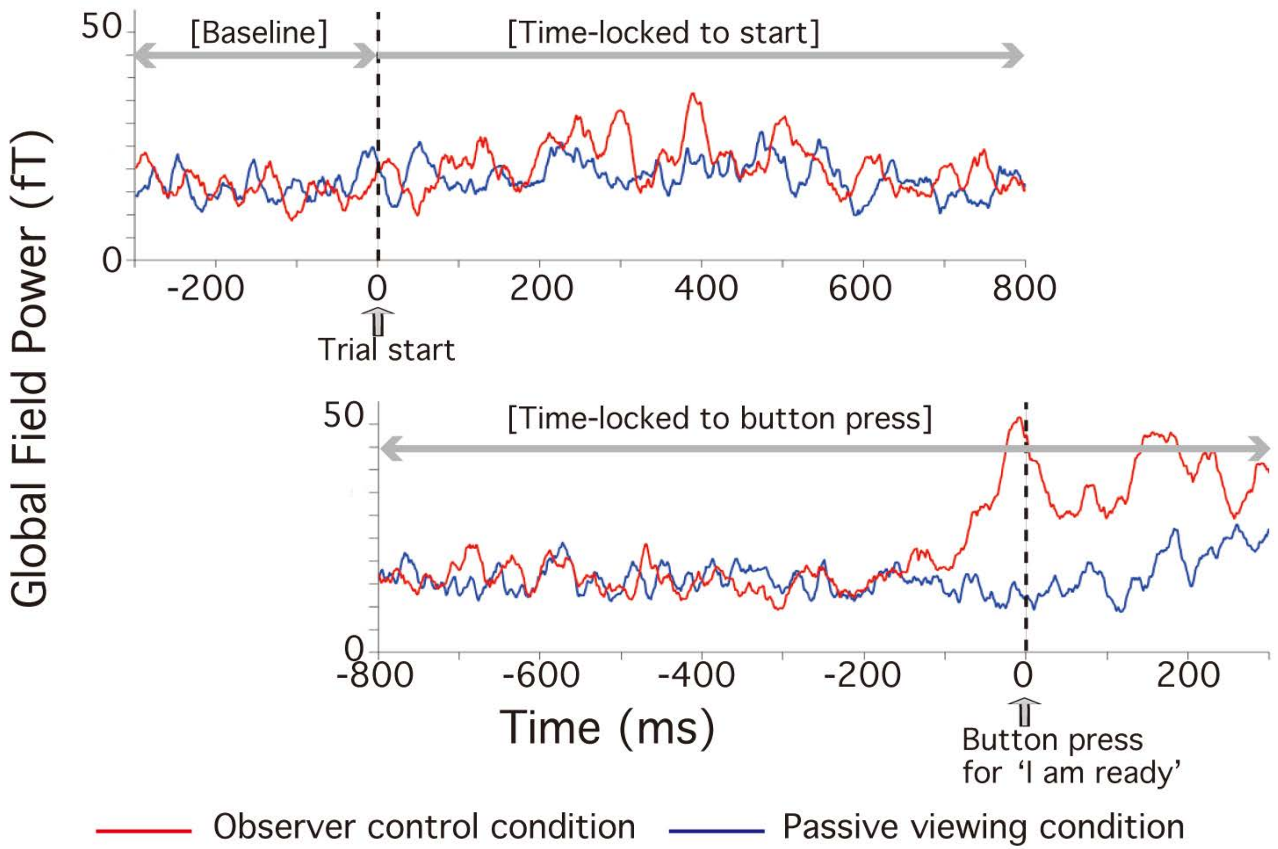


Random effect (n = 10)
Observer control – Passive (p = 0.001 uncorrected)

Which brain areas have important roles for this mechanism?

Estimated currents were arranged into 2 groups:

A. Time locked to start B. Time locked to button press for ‘ I am ready’



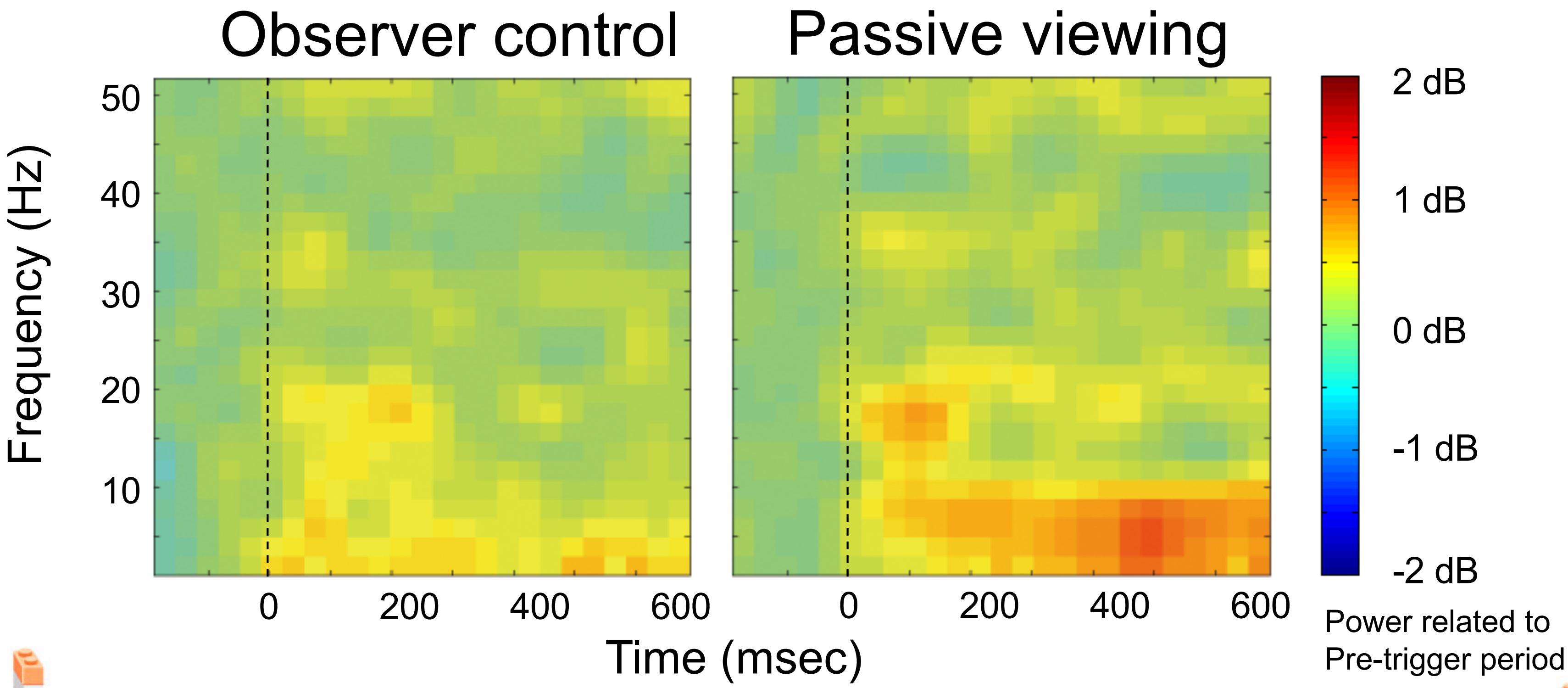
Which brain areas have important roles for this mechanism?

Estimated currents were analyzed by

1. Time-frequency analysis
2. Task-performance correlation analysis
(Brain activity vs. performance)

1. Time-frequency analysis

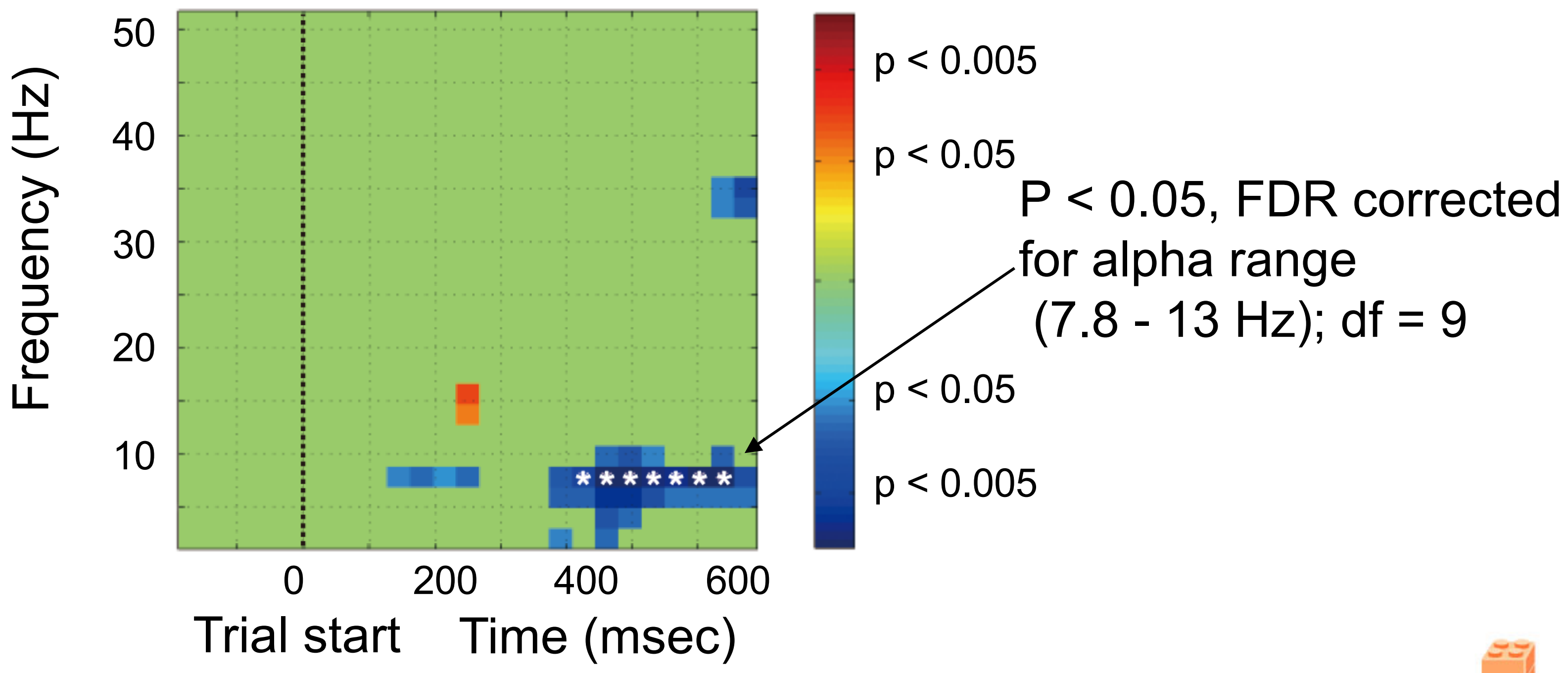
A. Time locked to start: rCMA



1. Time-frequency analysis

A. Time locked to start: rCMA

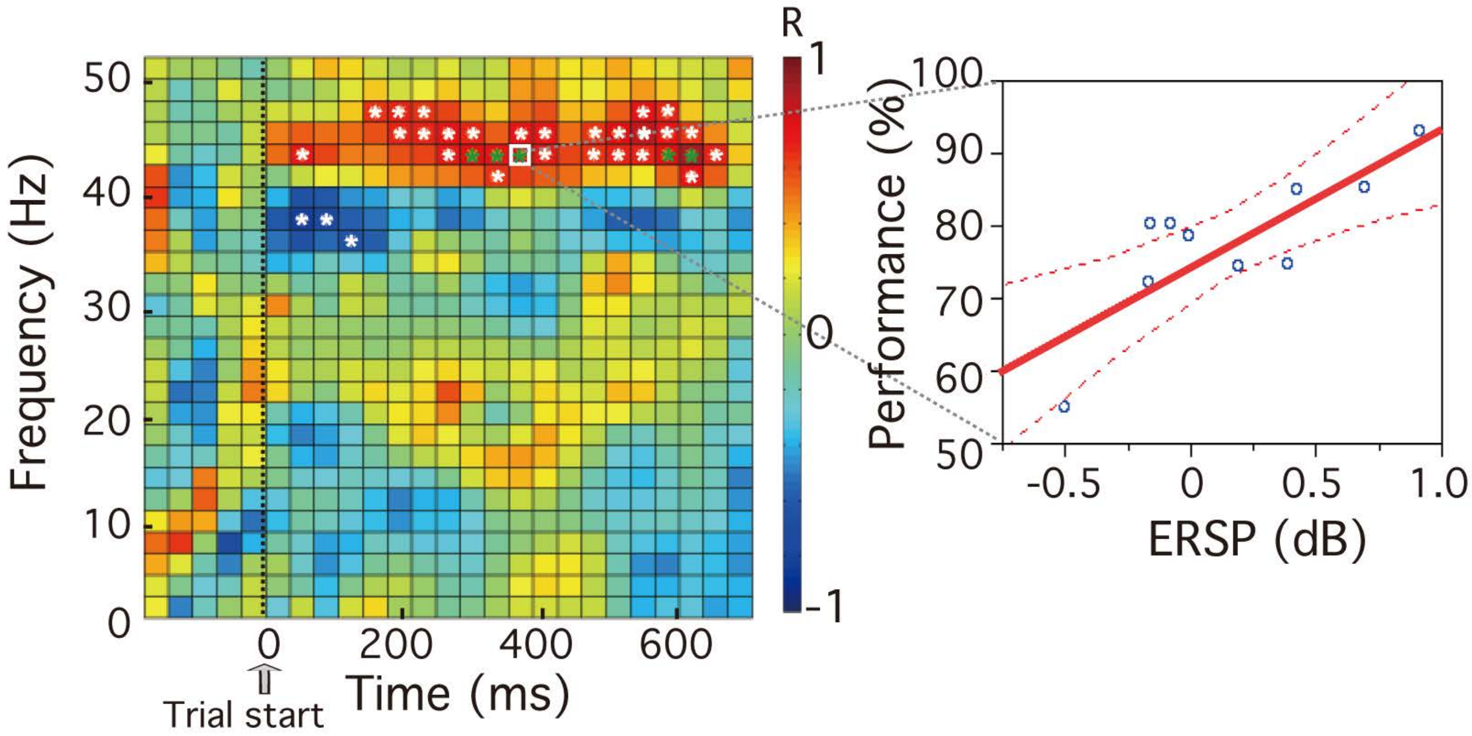
Statistical significant map (Observer control vs. Passive)



2. Task-performance correlation analysis

A. Time locked to start: rCMA

Correlation coefficient, r, between
frequency power changes (ERSP) and task performance

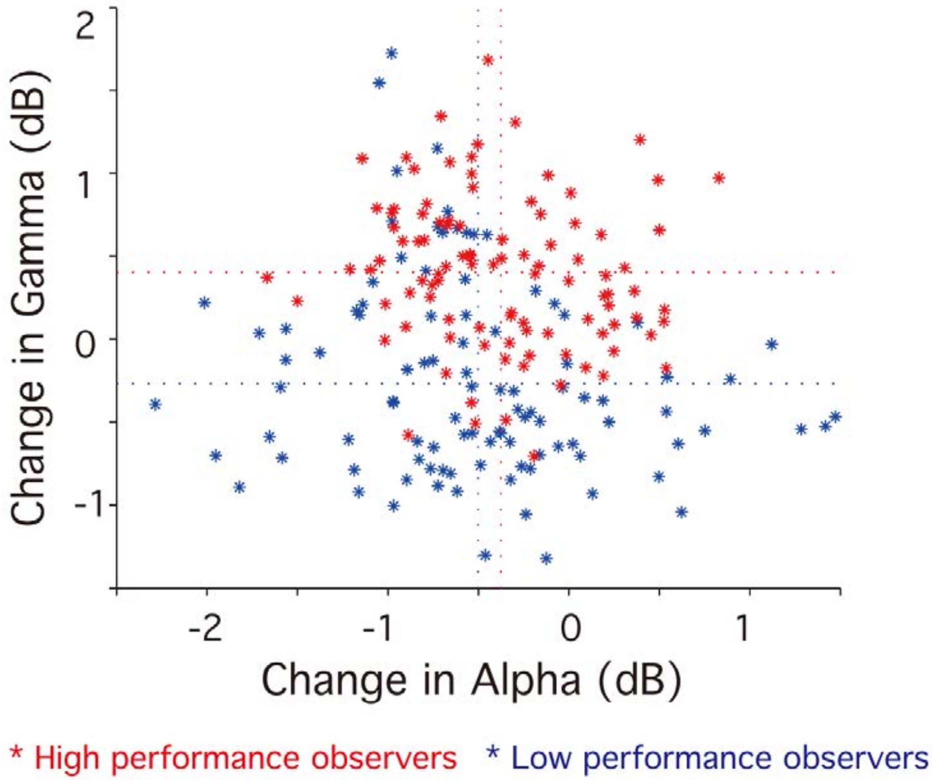


* p < 0.05

2. Task-performance correlation analysis

A. Time locked to start: rCMA

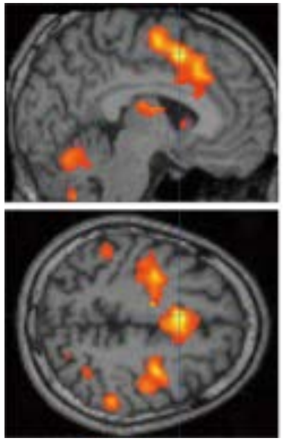
Relationship between alpha and gamma modulations



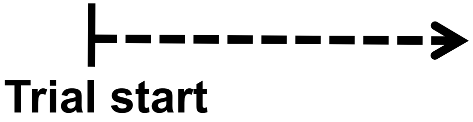
Summary of Brain imaging studies

rCMA

*a. There was a sustained depression of **alpha** activity (7-13Hz) beginning approximately 450 msec after trial start.*



*b. **Gamma**-band power (41-47 Hz) within this area was positively correlated with task performance from 150 – 640 msec after the trial start.*



Which brain areas have important roles for this mechanism?

rCMA may have important roles in monitoring internal attentional states.

Alpha band activity and gamma band activity may have different roles:

- Alpha suppression may reflect a strengthening of top-down inter-areal connections.
- A positive correlation between gamma activity and task performance indicates that gamma may play an important role in guiding visuomotor behavior.

When you are ready …

Can you tell when you are ready?
YES.

When you are ready, is your performance better?
YES.

Which brain areas have important roles for this mechanism?
rCMA.

Consciousness and ...

Attention

Readiness

Attention

auditory

demo

E N D

Thank you for your attention!