



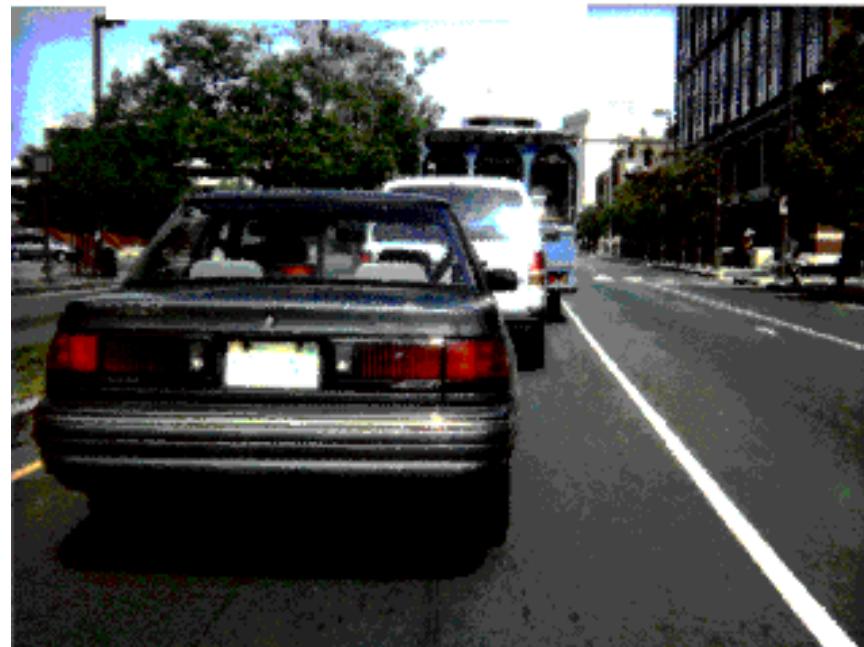
Long-distance Synchronization of Neural Activity across Cortical Areas Correlates with Conscious Perception

Lucia Melloni



What happens in our brain when we
consciously perceive?

What do we see?



What do we not see?

We did not see this!



What do we see?

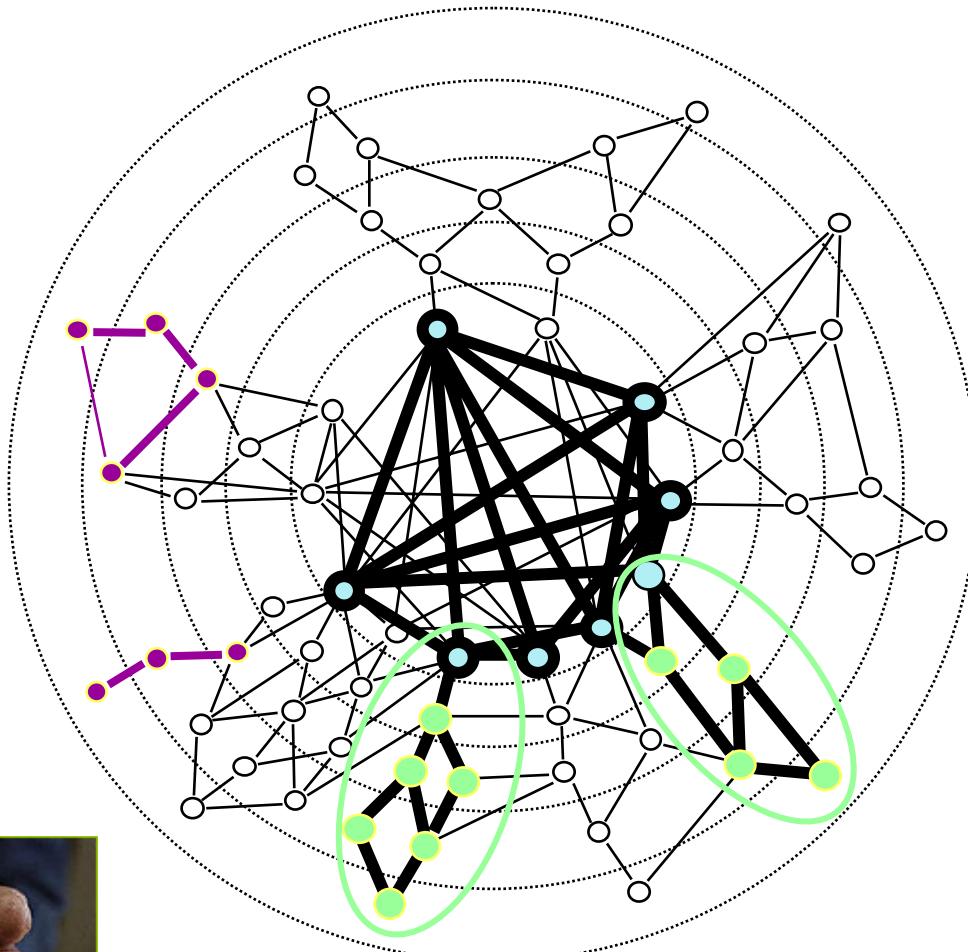


Once again there was something we missed!



- Some information is processed without awareness (words, faces, pictures, etc).
 - Blindsight, unilateral hemineglect
 - Subliminal priming, attentional blink
- What distinguishes conscious from unconscious processing of information?

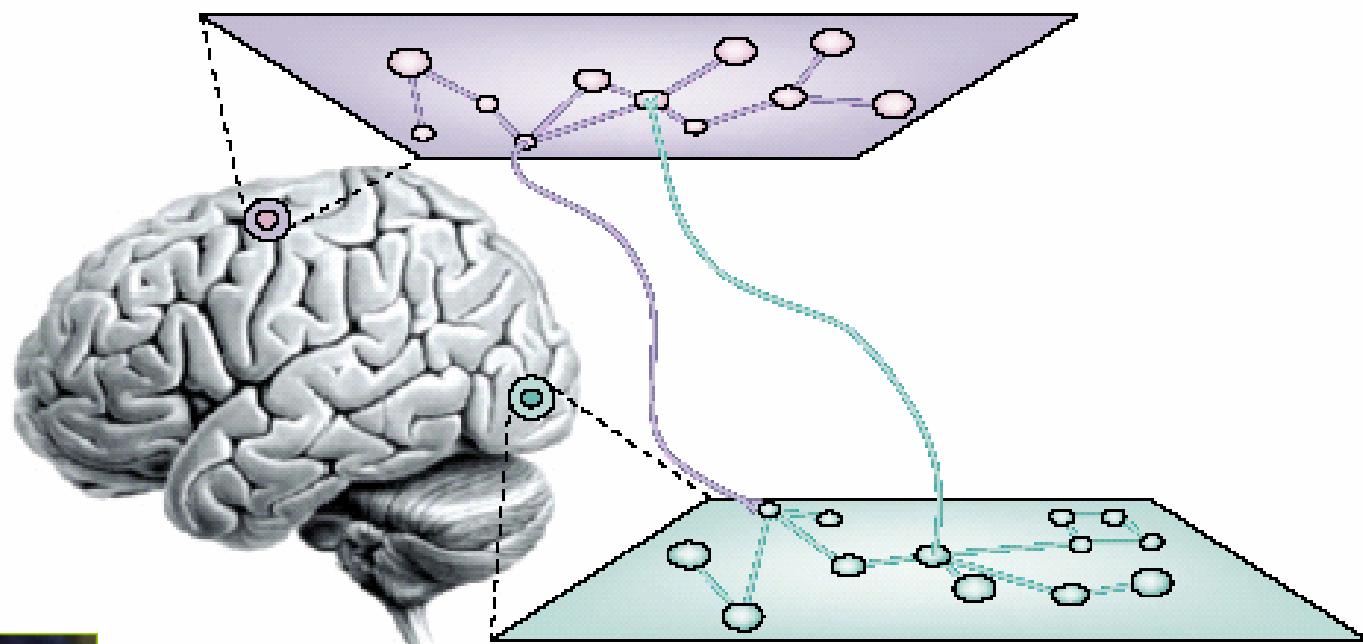
A schematic representation of the workspace model



Dehaene, Kerszberg & Changeux, *PNAS*, 1998
inspired by Mesulam, *Brain*, 1998

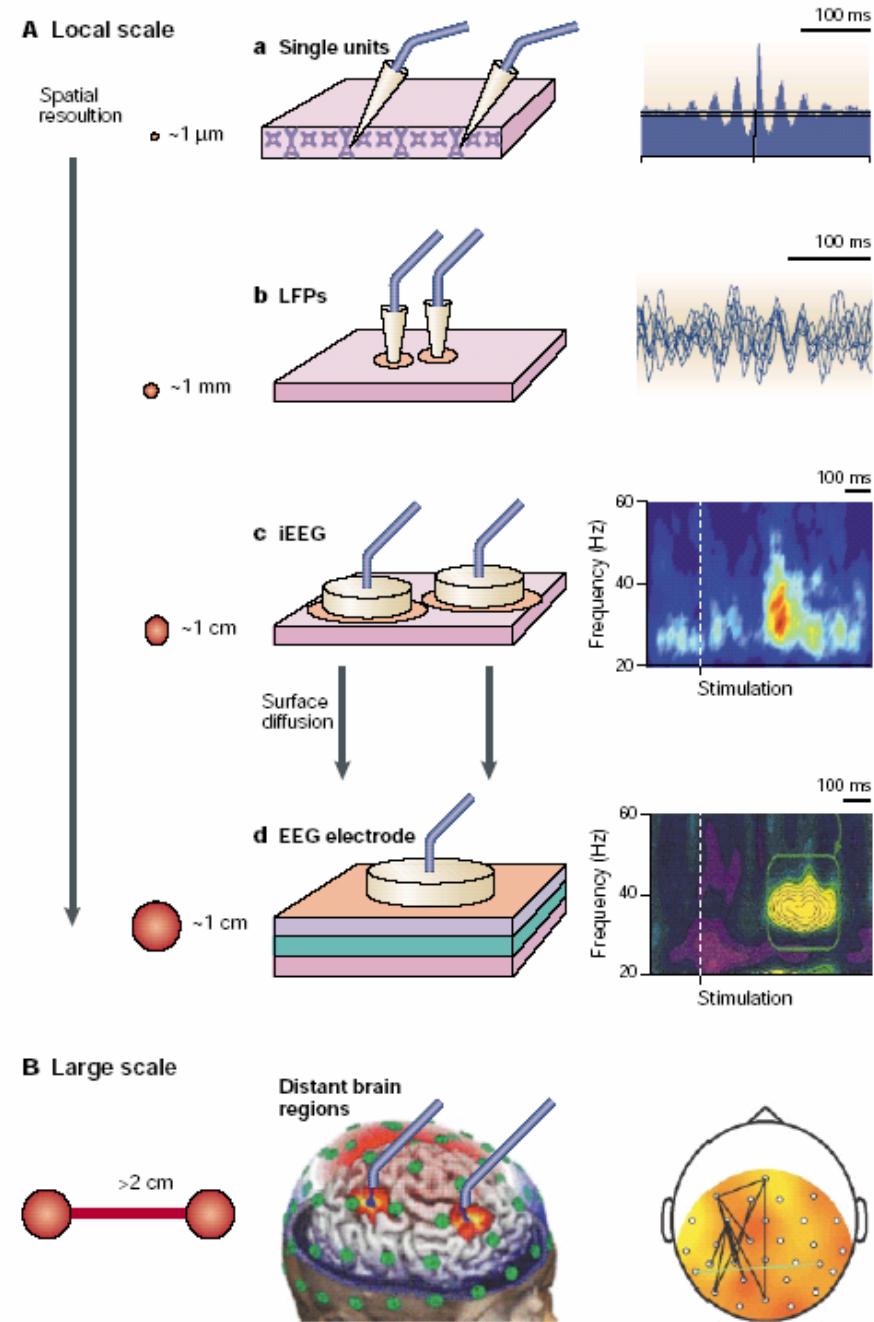
Neural correlate of consciousness?

SYNCHRONIZATION OF DISTRIBUTED NEURAL ASSEMBLIES



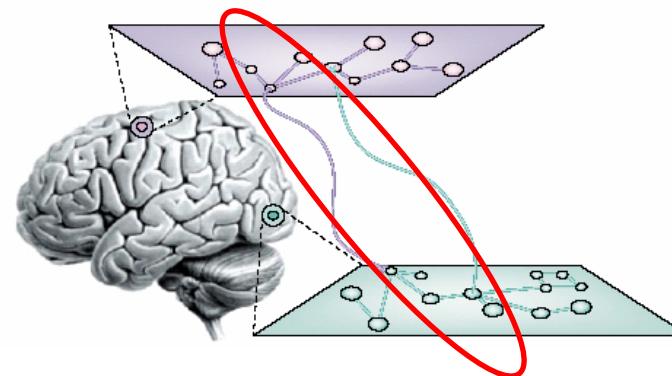
Varela et al., 2001. Nature Rev. Neurosci

Neural synchrony
can be found at different
spatial scales.
Then, what is the
spatial scale that correlates
with conscious perception?

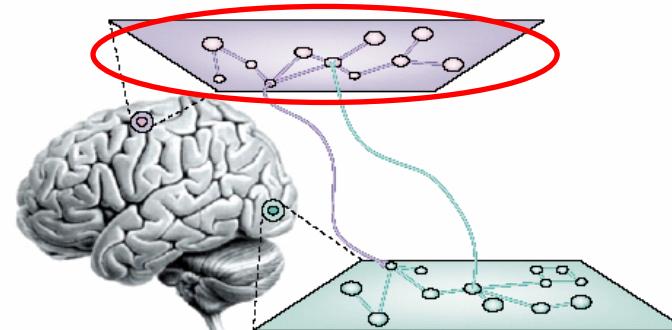


Hypothesis

- Conscious integration of information is correlated with long-distance neural synchrony.

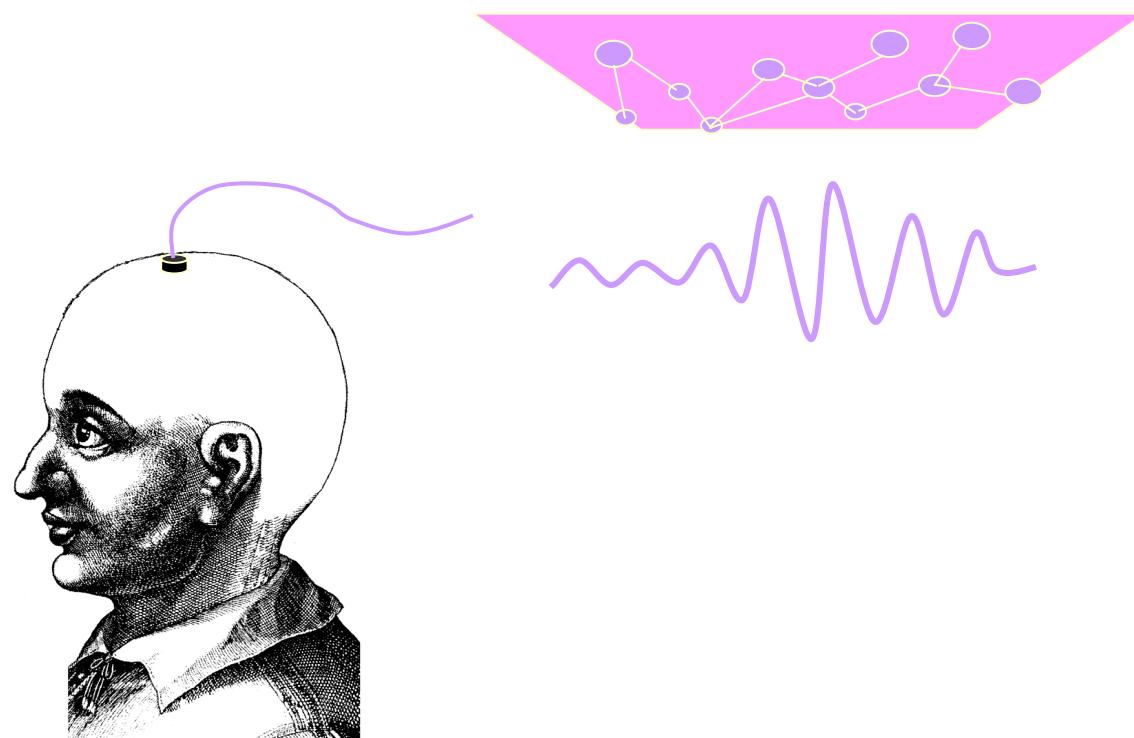


- Unconscious integration of information is correlated with local neural synchrony.



Methods

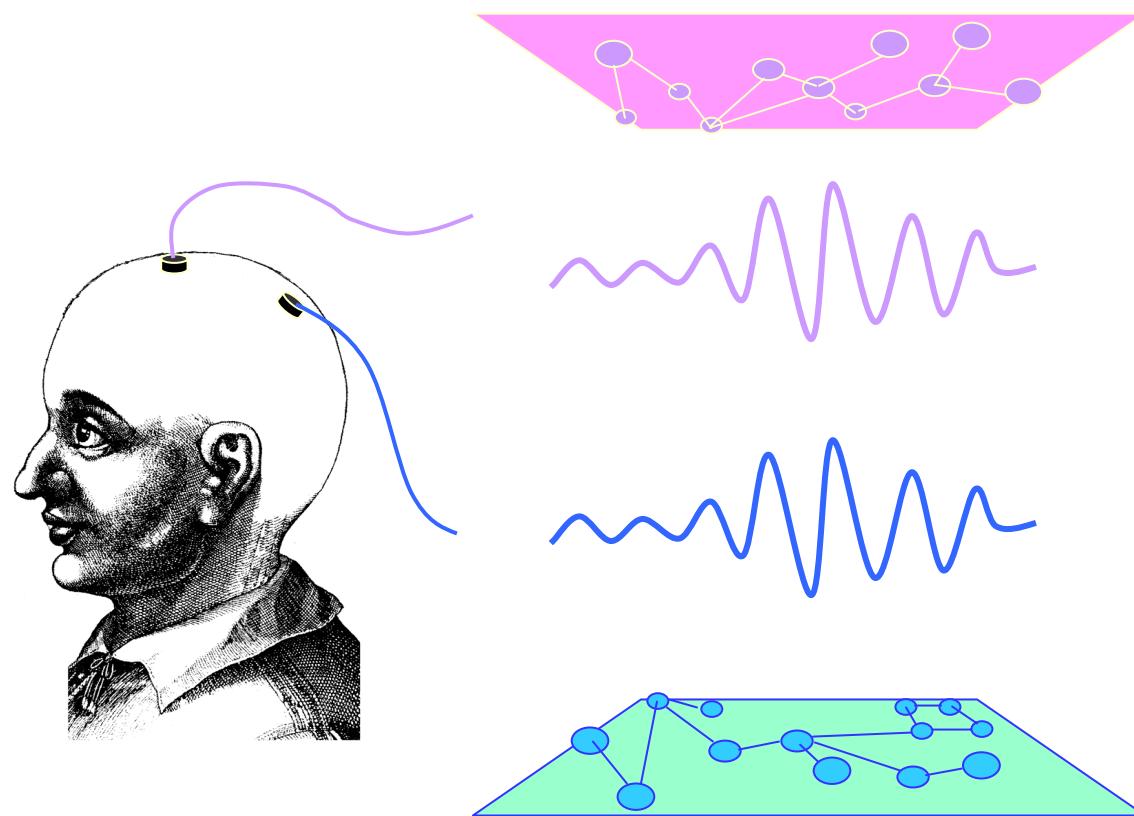
Spectral power (**Local Synchrony**)



Varela et al., 2001. Nature Rev. Neurosci

Methods

Phase synchrony (**Global Synchrony**)

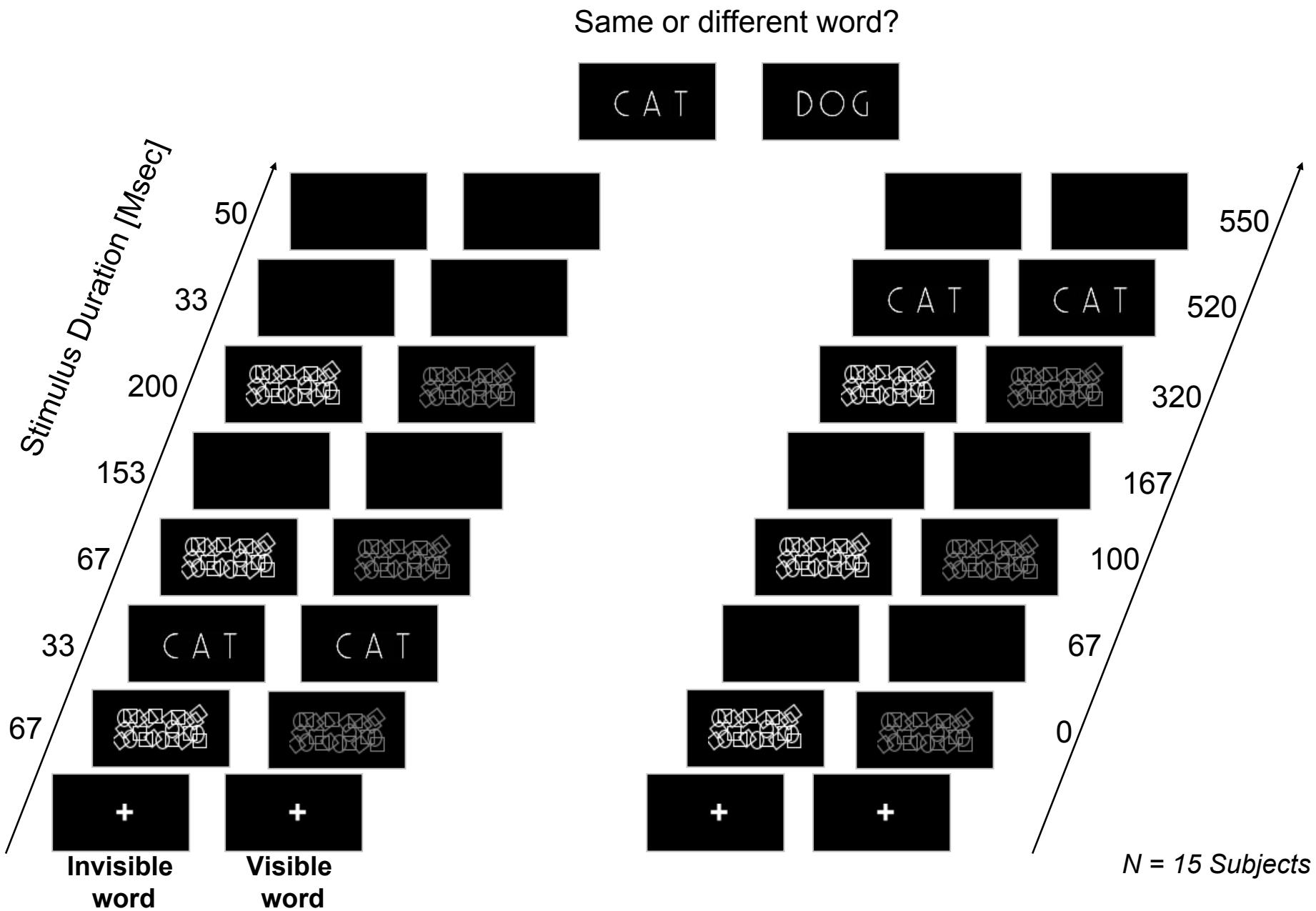


Varela et al., 2001. Nature Rev. Neurosci

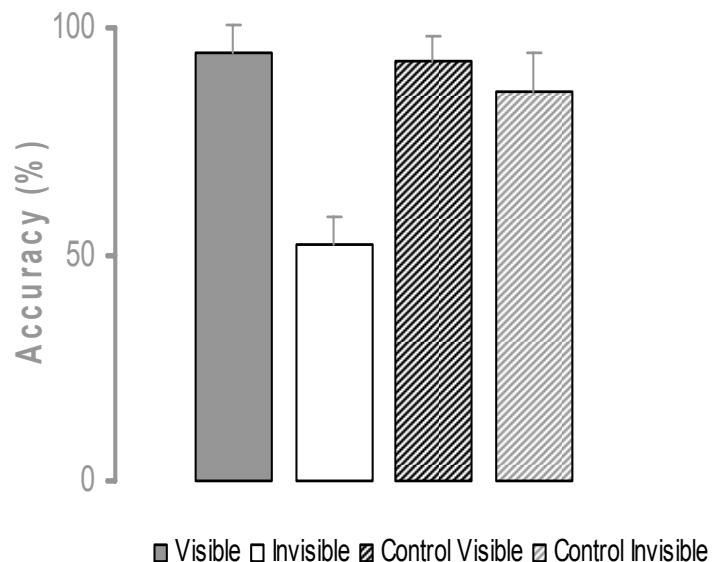
Experimental procedure

- Manipulation of stimulus visibility
 - Visible vs. invisible stimuli
- Electroencephalographic measurements
 - Spectral power \approx local neural synchrony
 - Phase-synchrony \approx long-distance neural synchrony

1. Visibility Experiment: Delayed-match to sample task

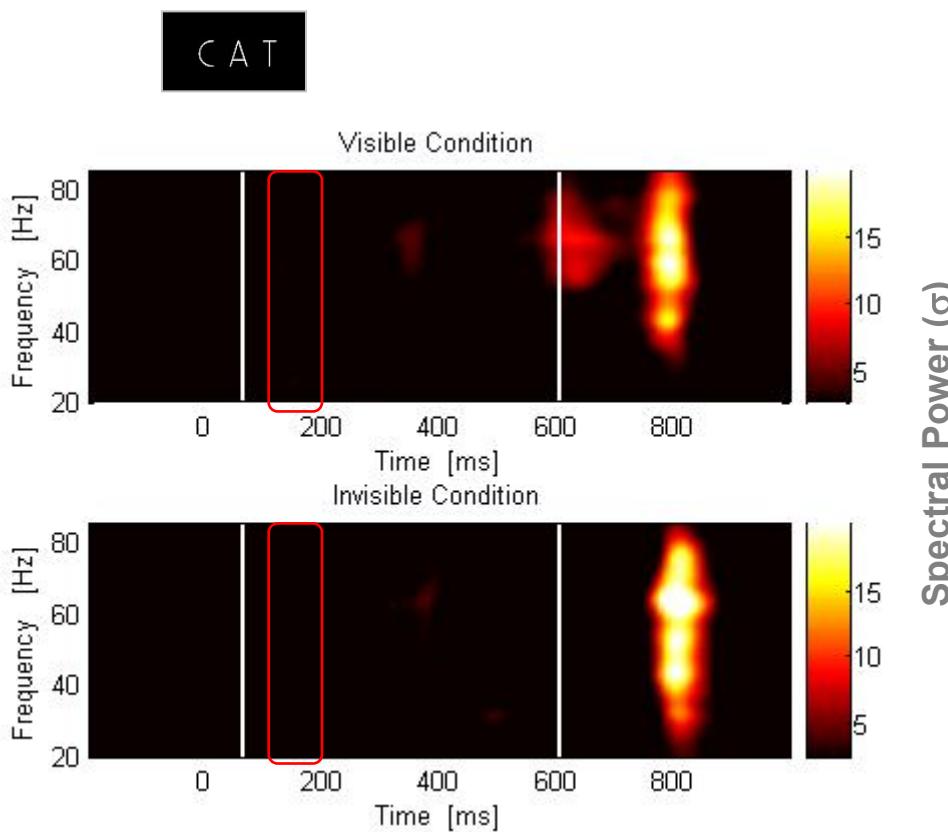


Behavioral measures of word's visibility



	Visible	Invisible	Control Visible	Control Invisible
d'	3.85	0.16	3.27	2.50
Hits (%)	94.58	52.25	92.50	86.17

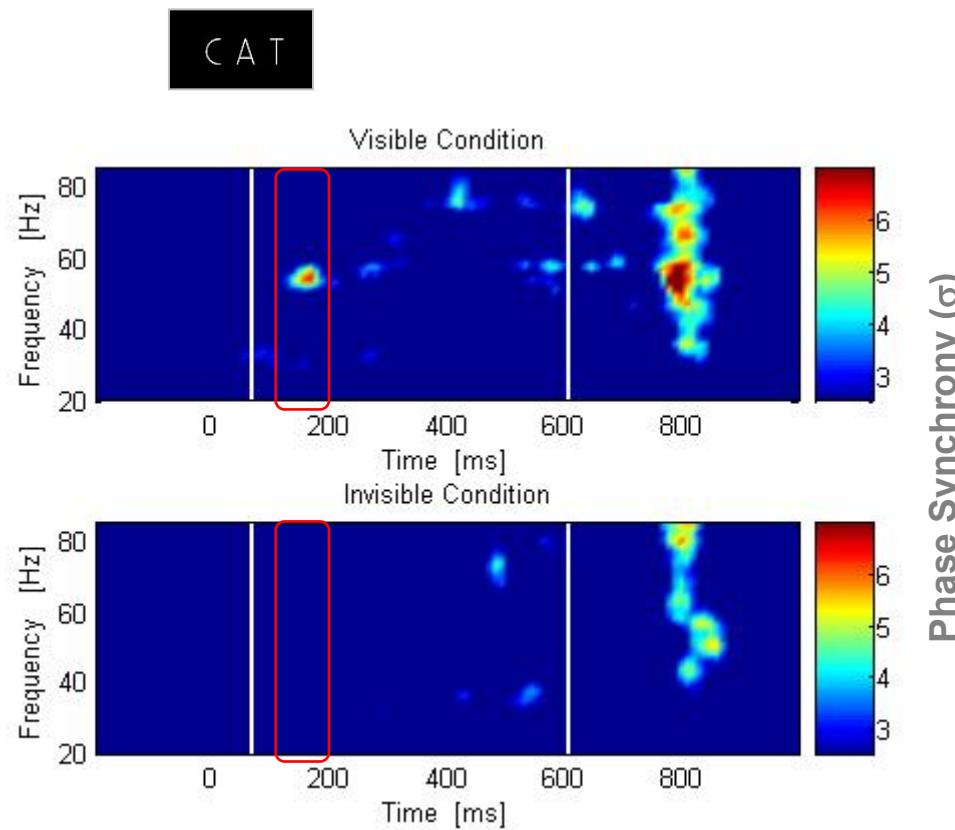
Spectral Power



Visible Condition : Visible – Control Visible

Invisible Condition : Invisible – Control Invisible

Long-distance synchronization



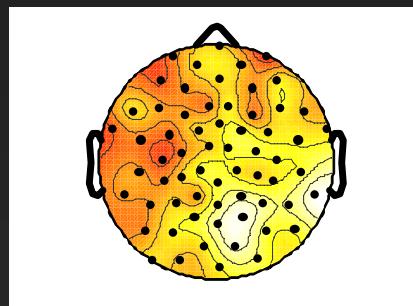
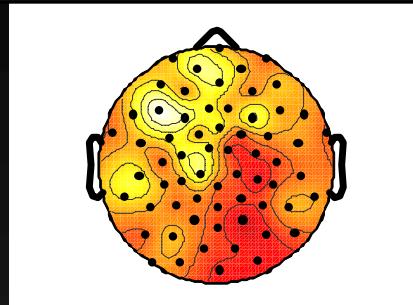
Visible Condition : Visible – Control Visible

Invisible Condition : Invisible – Control Invisible

- 50-57 Hz

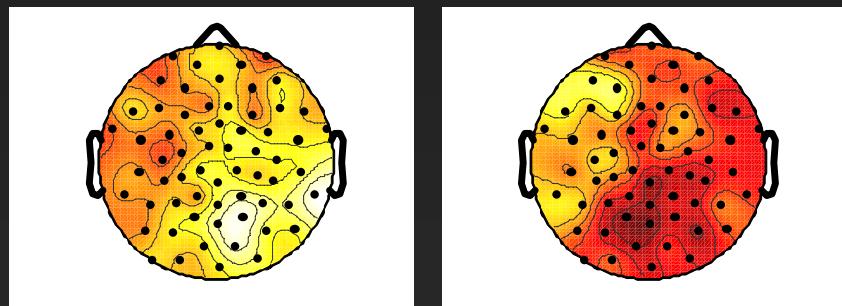
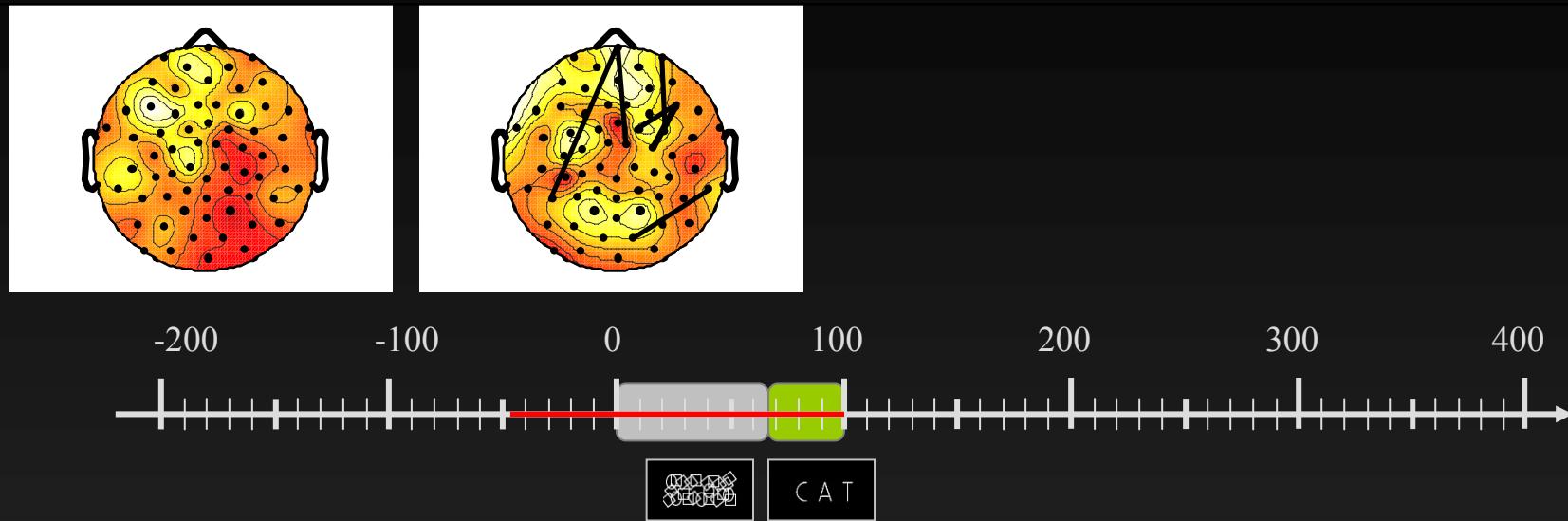
- 80-130 ms after masked-word presentation

Visible Condition



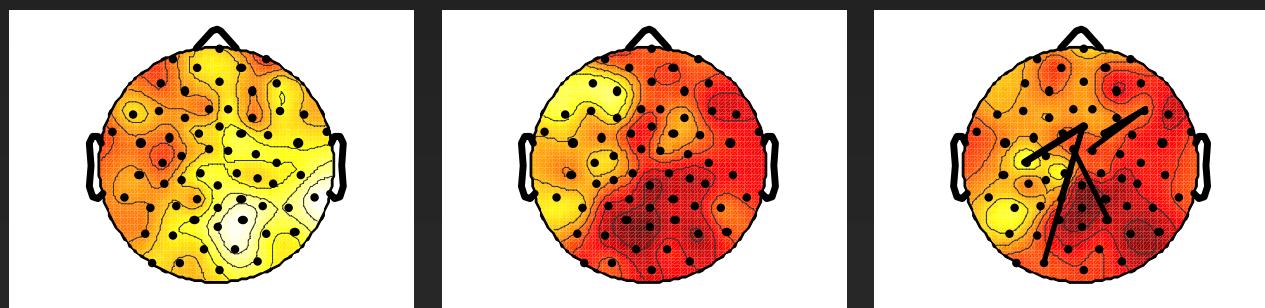
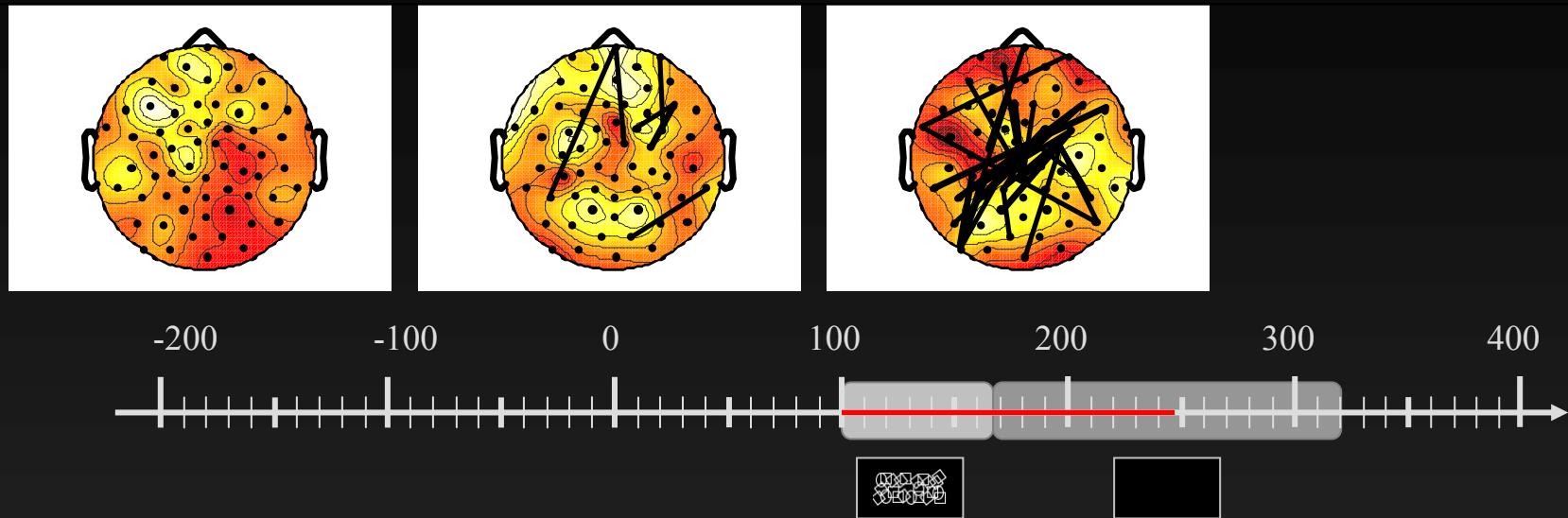
Invisible Condition

Visible Condition



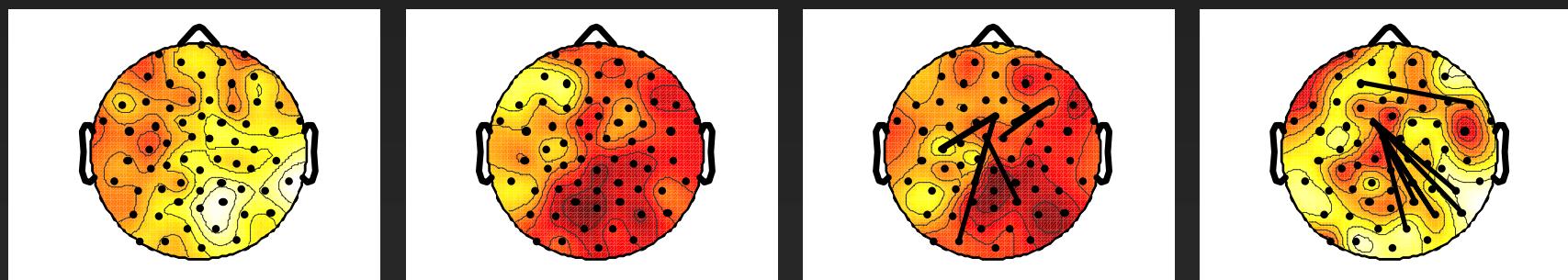
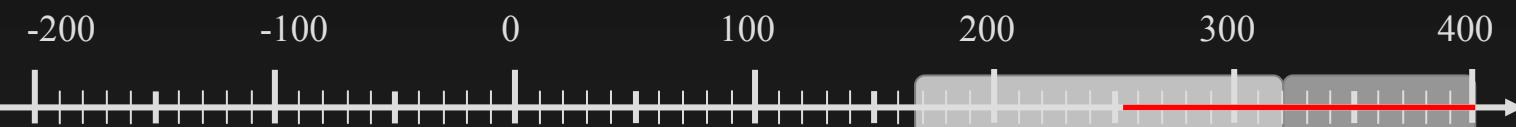
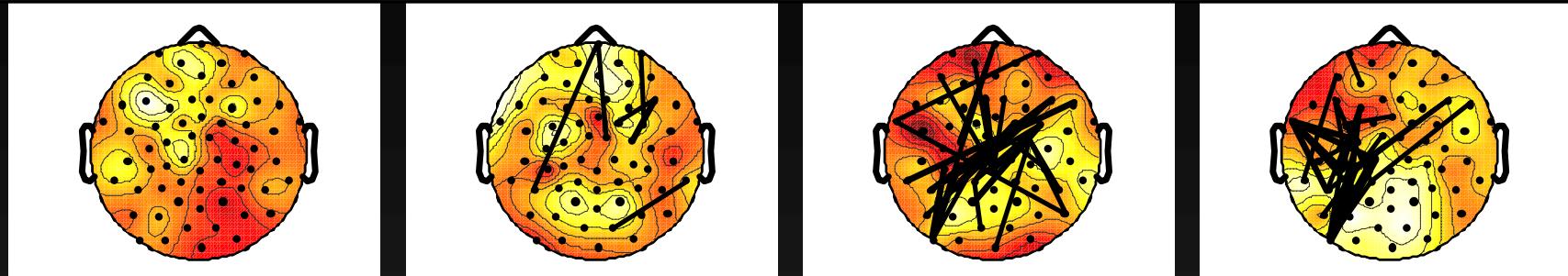
Invisible Condition

Visible Condition



Invisible Condition

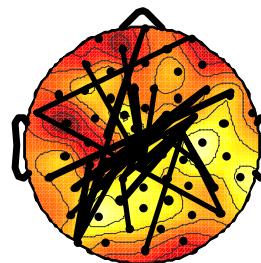
Visible Condition



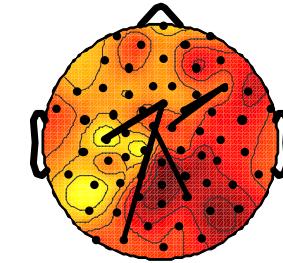
Invisible Condition

- What distinguishes conscious from unconscious processing of information?

Long-distance synchrony
fast ~ 100ms!



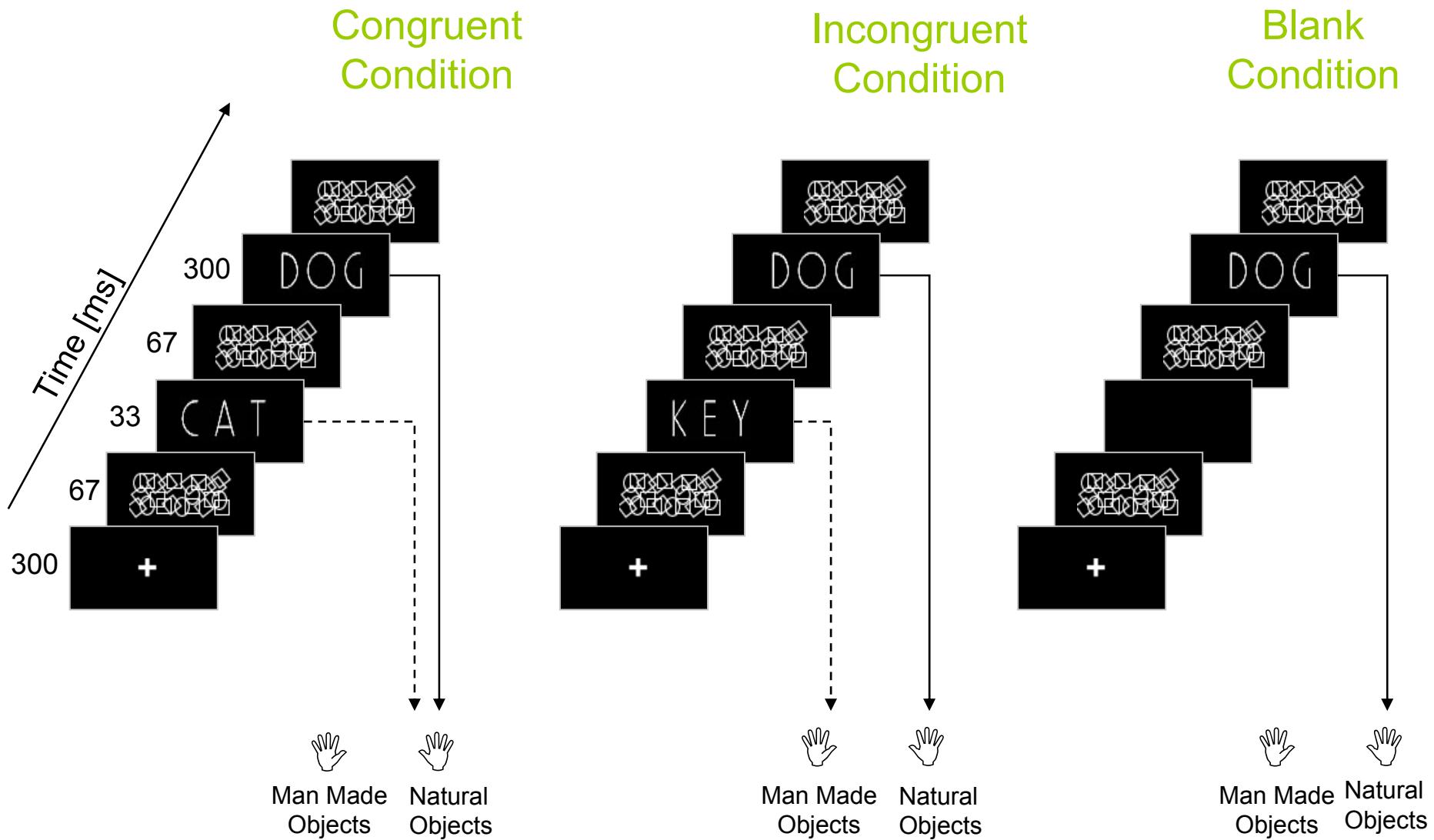
Visible Condition



Invisible Condition

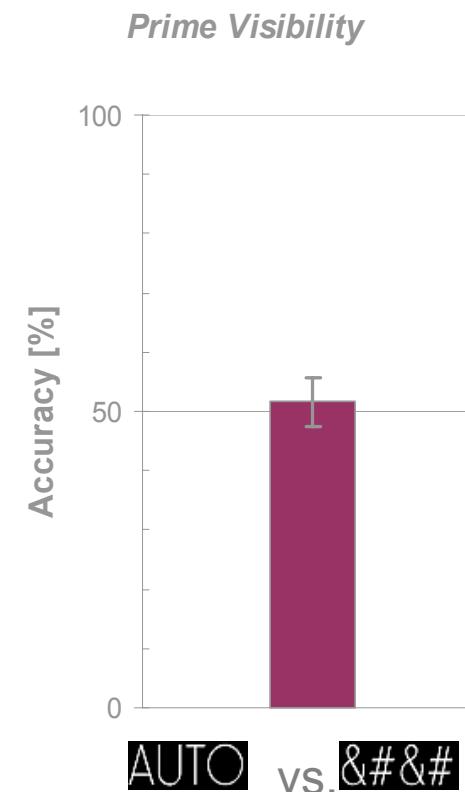
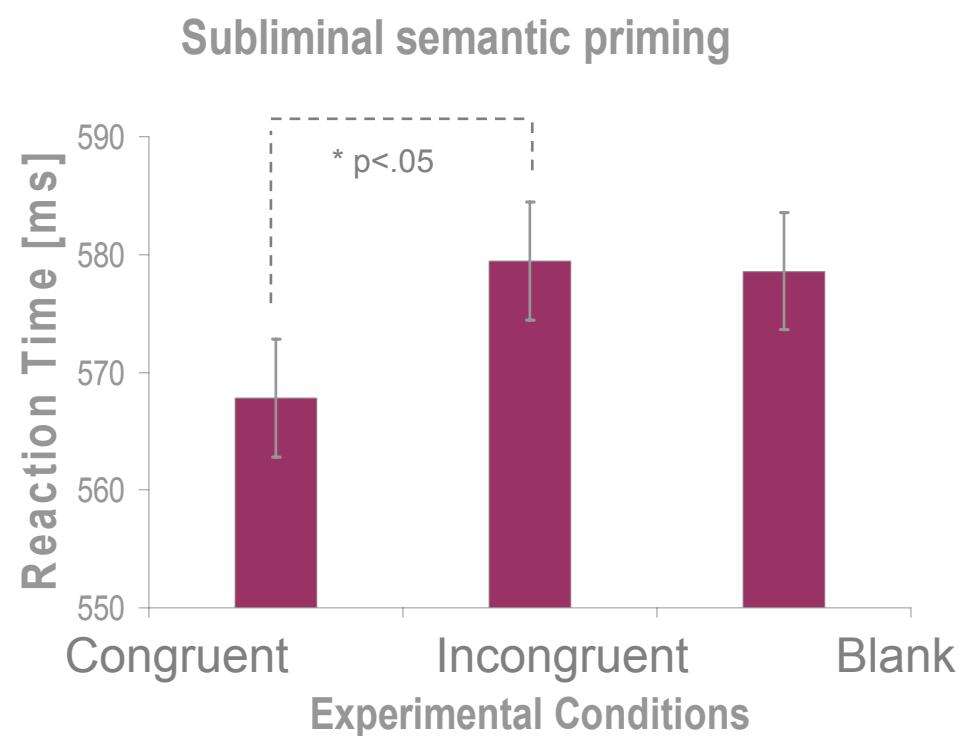
- Long-range neural synchrony could reflect:
 - A specific mechanism associated with awareness or,
 - The depth of processing in the various cortical areas involved in written word processing.
- How to disentangle both hypothesis?
 - Subliminal semantic priming experiment.
 - High-level processing of information WITHOUT awareness

2. Subliminal Semantic Priming Experiment

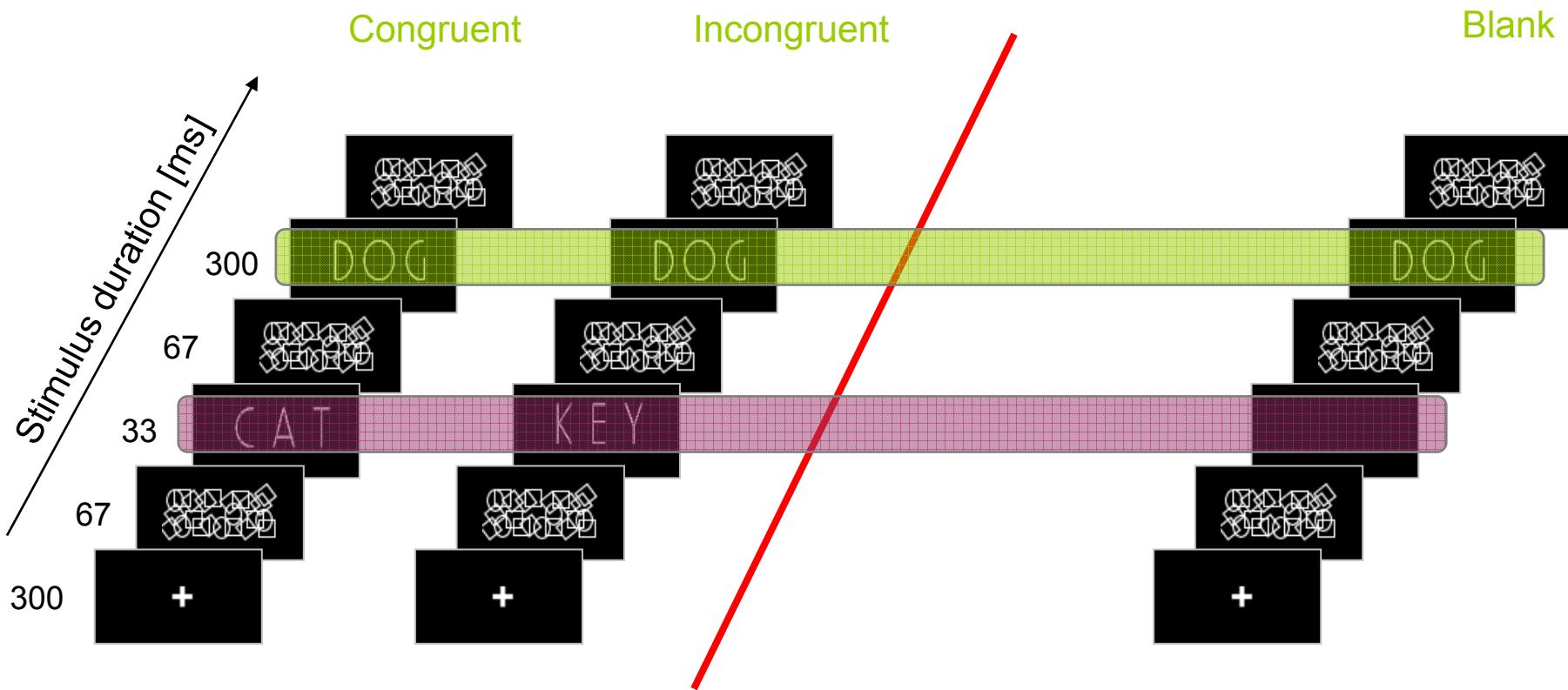


N=19 subjects

Behavioral measures of subliminal perception



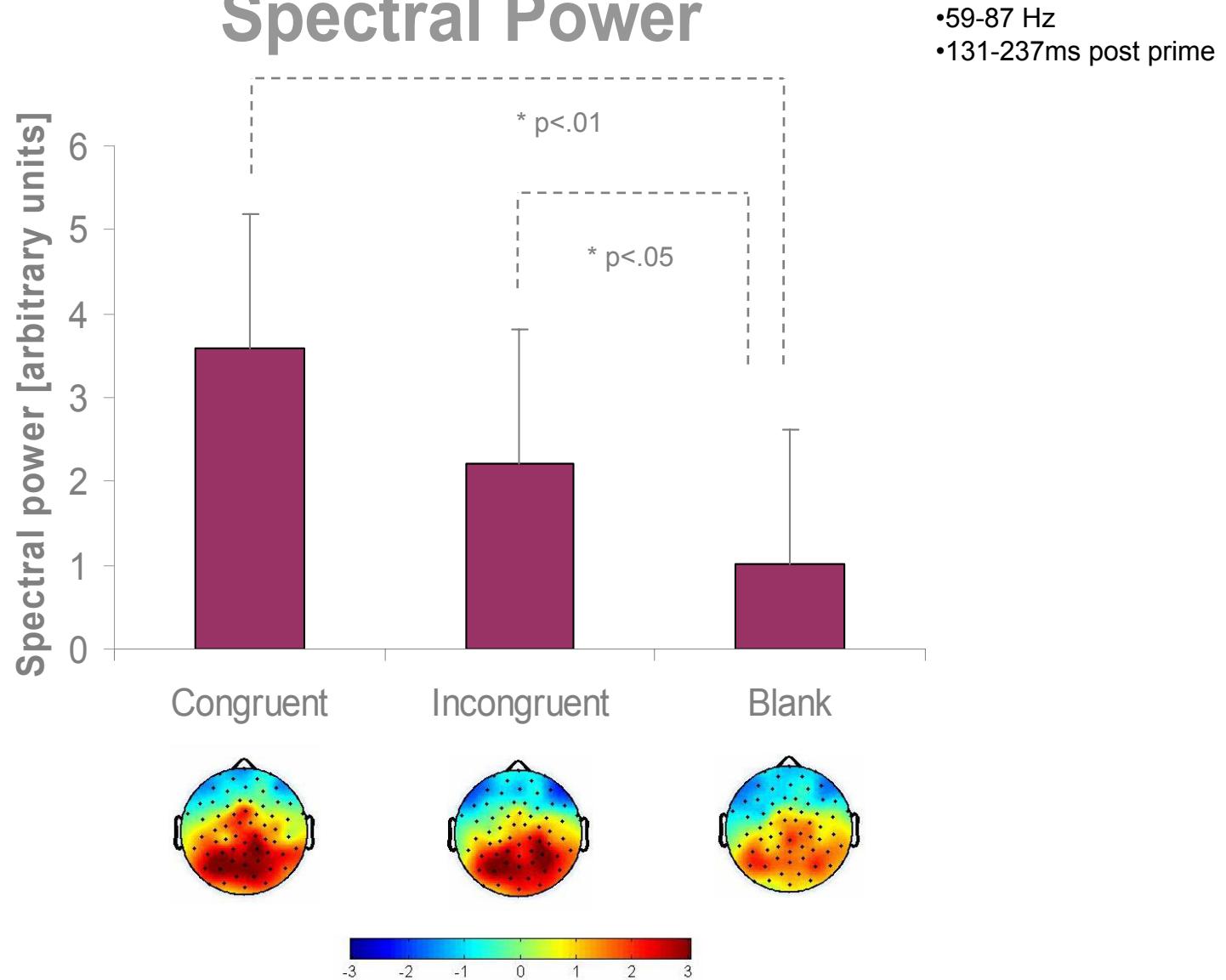
2. Subliminal Semantic Priming Experiment



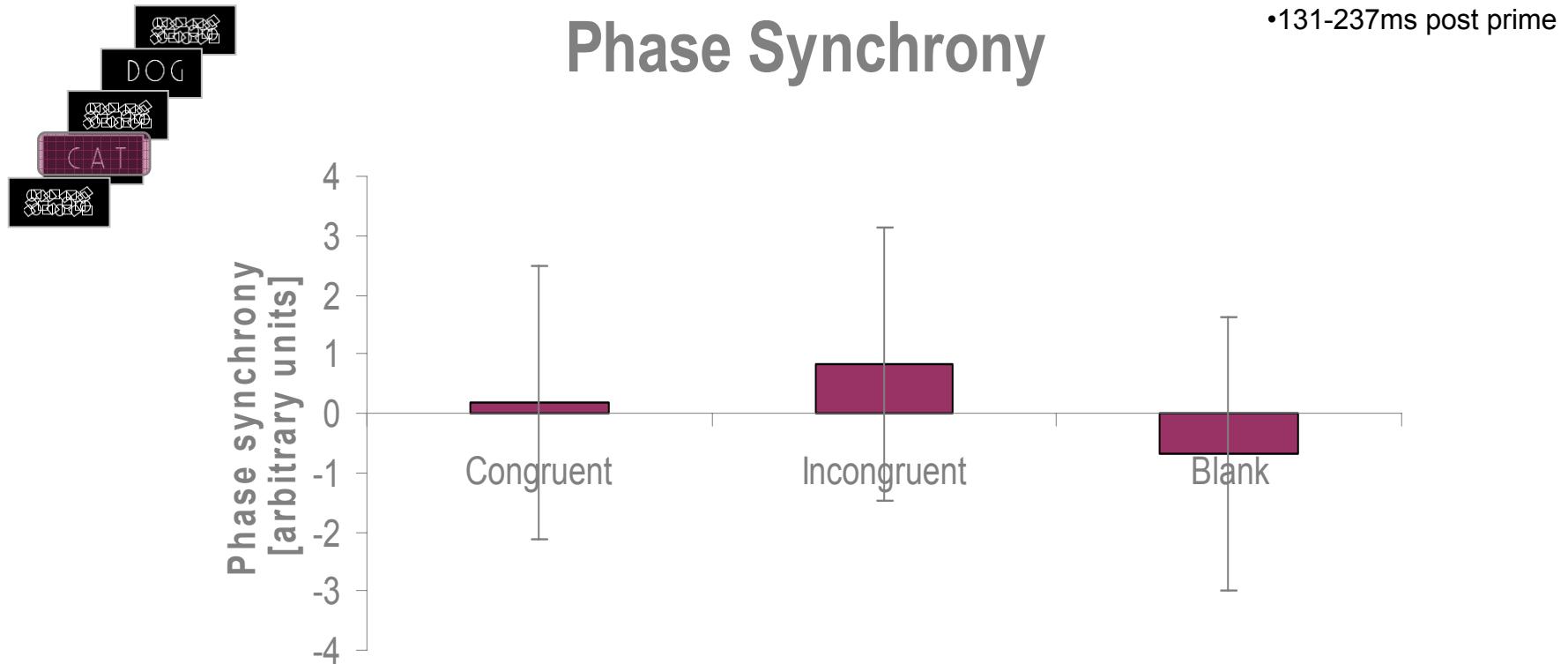
Cerebral response to the prime



Spectral Power



Cerebral response to the prime

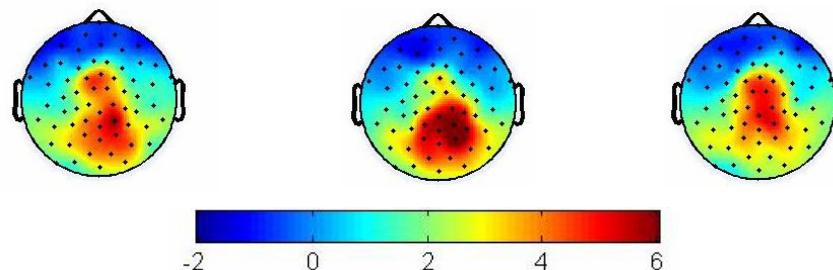


Cerebral response to the target



Spectral Power

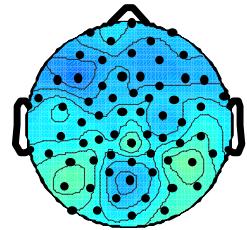
- 69-86 Hz
- 312-626 ms post prime



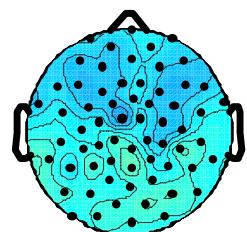
Cerebral response to the target



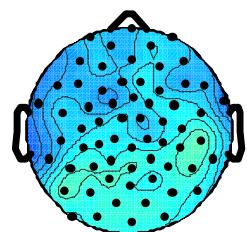
Congruent



Incongruent



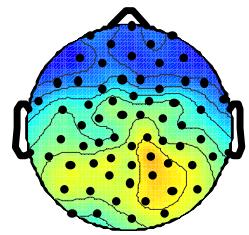
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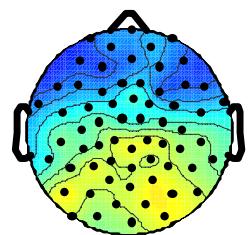
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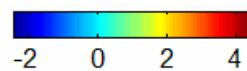
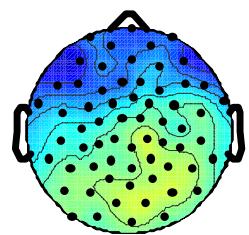
Congruent



Incongruent



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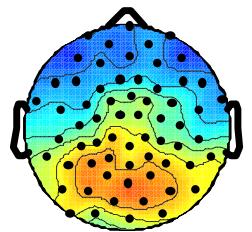


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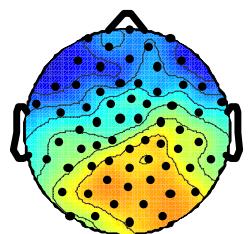


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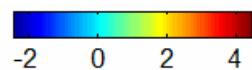
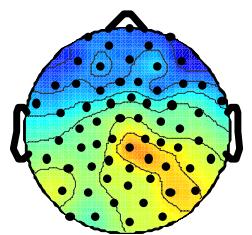
Congruent



Incongruent



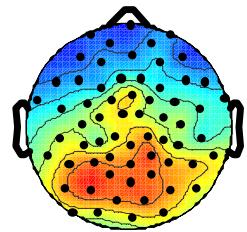
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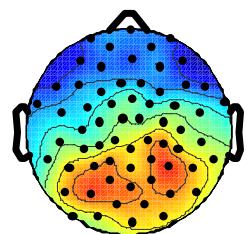
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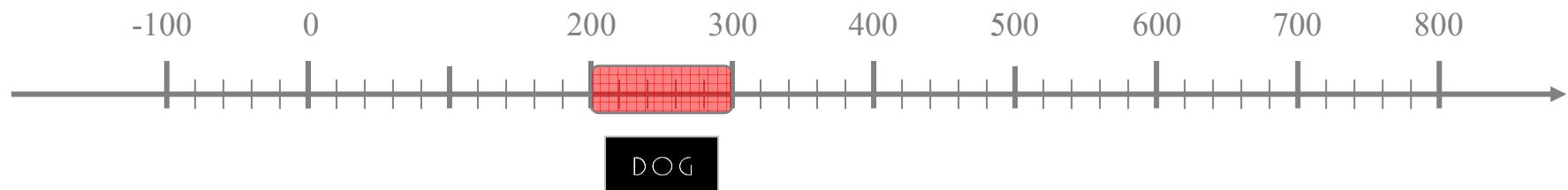
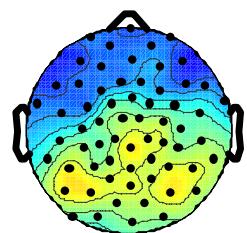
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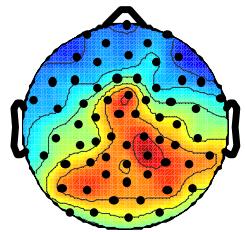
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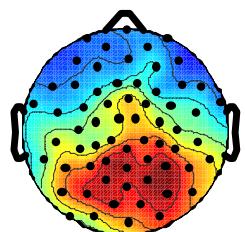
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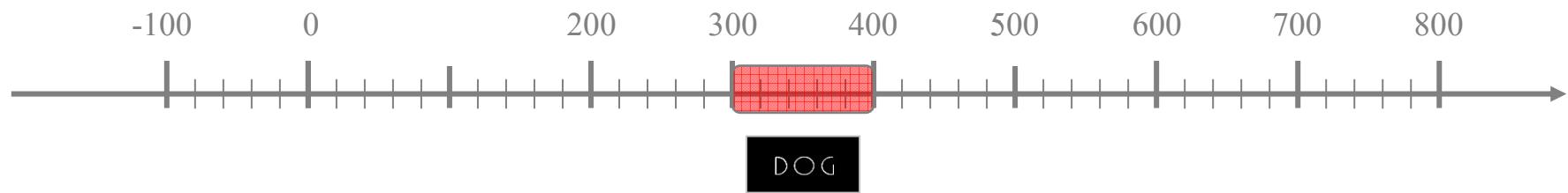
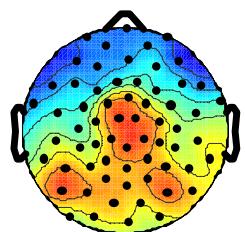
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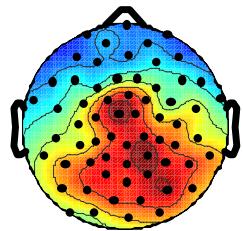
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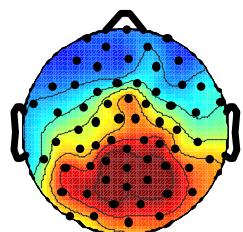
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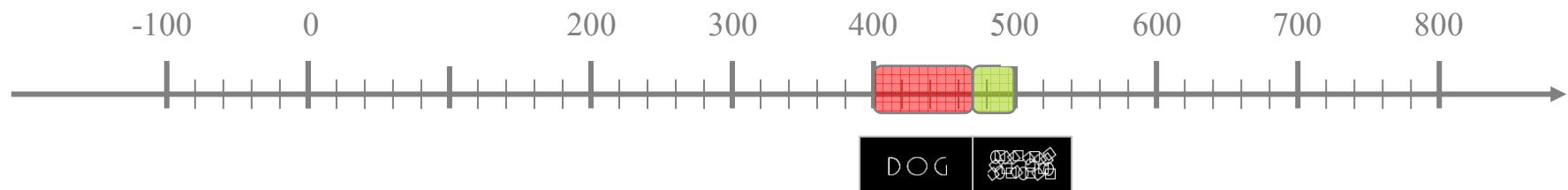
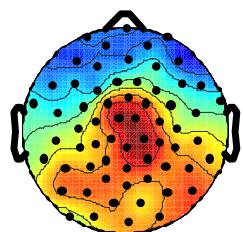
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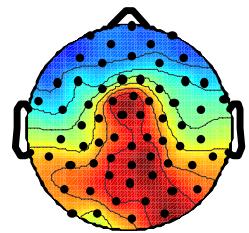
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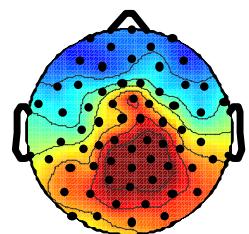
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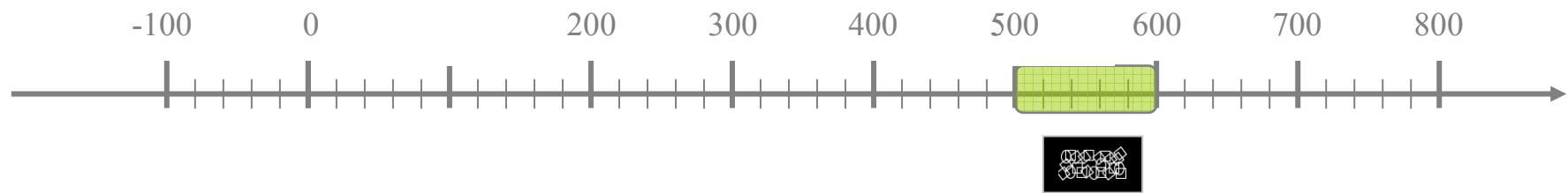
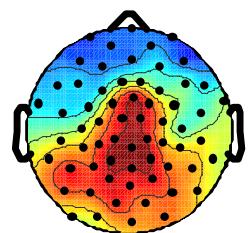
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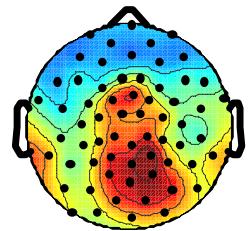
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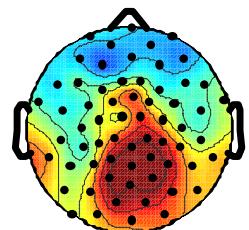
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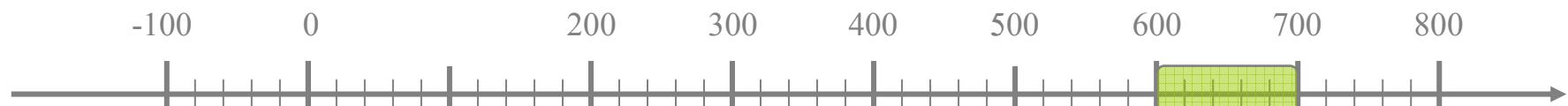
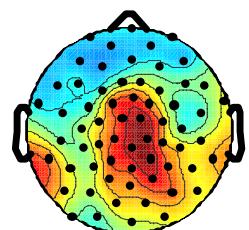
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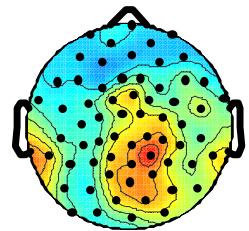
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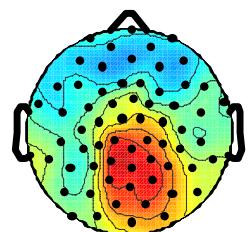
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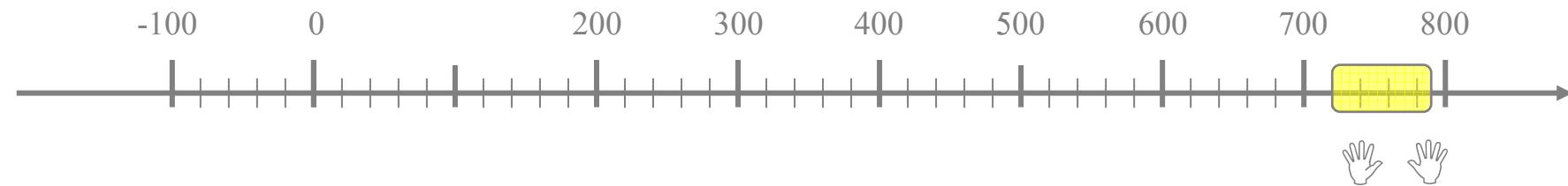
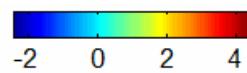
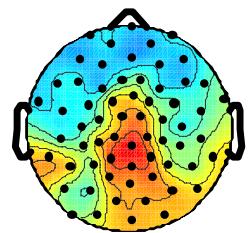
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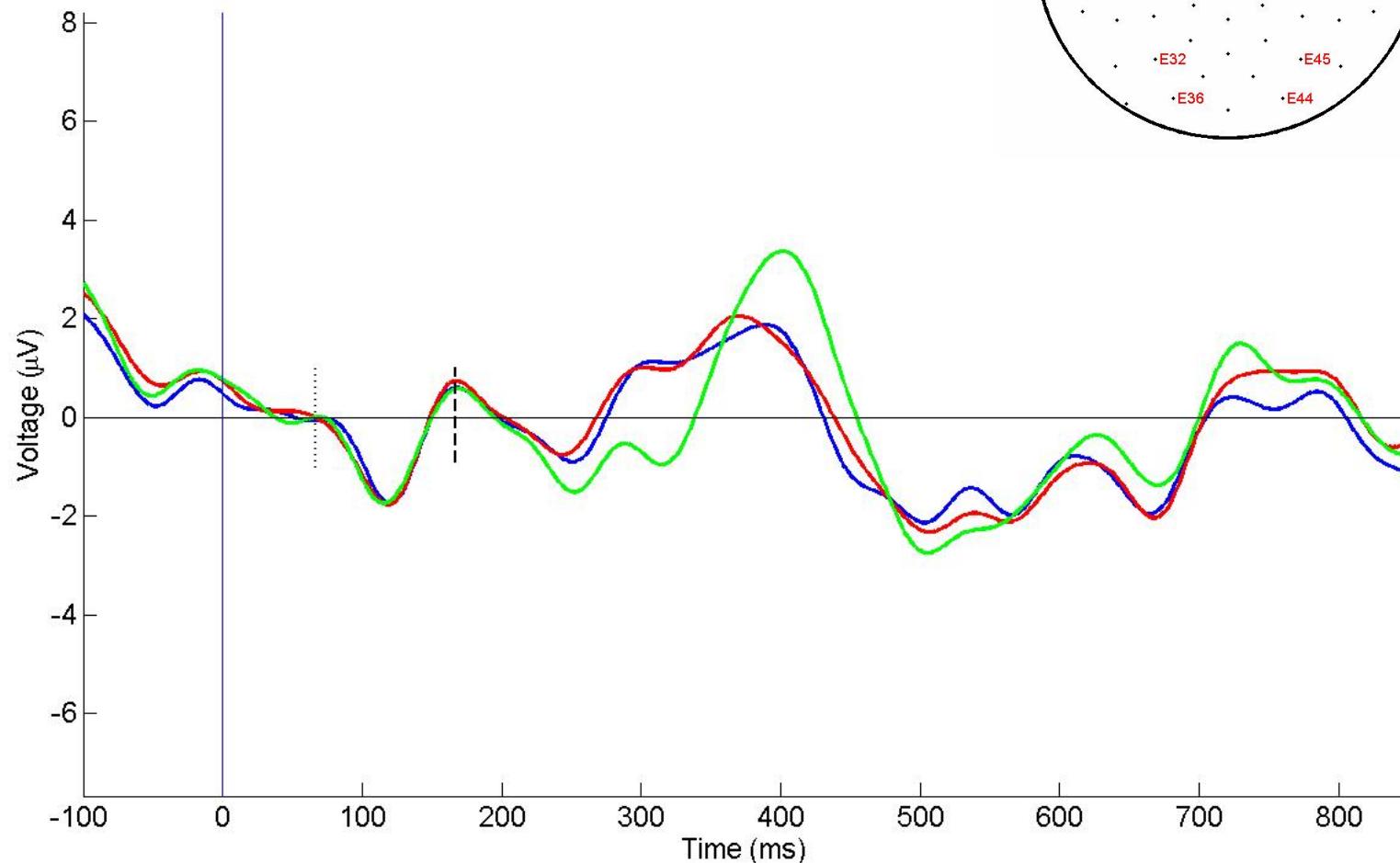


Event-related potential

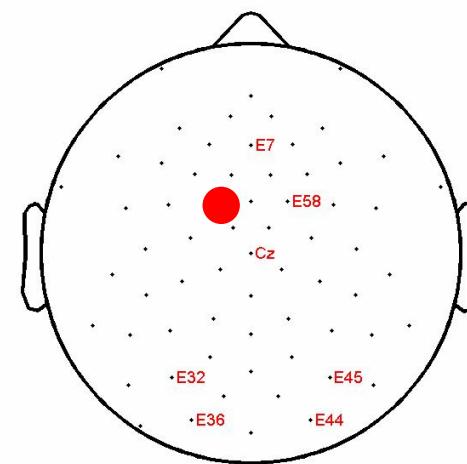
- ERP's related to sensory stimulation do not show differences between conditions (P1-N1)
- Thus, the difference in induced gamma oscillation cannot be attributed to a difference in sensory stimulation.

Anterior electrodes

- : Congruent
- : Incongruent
- : Blank

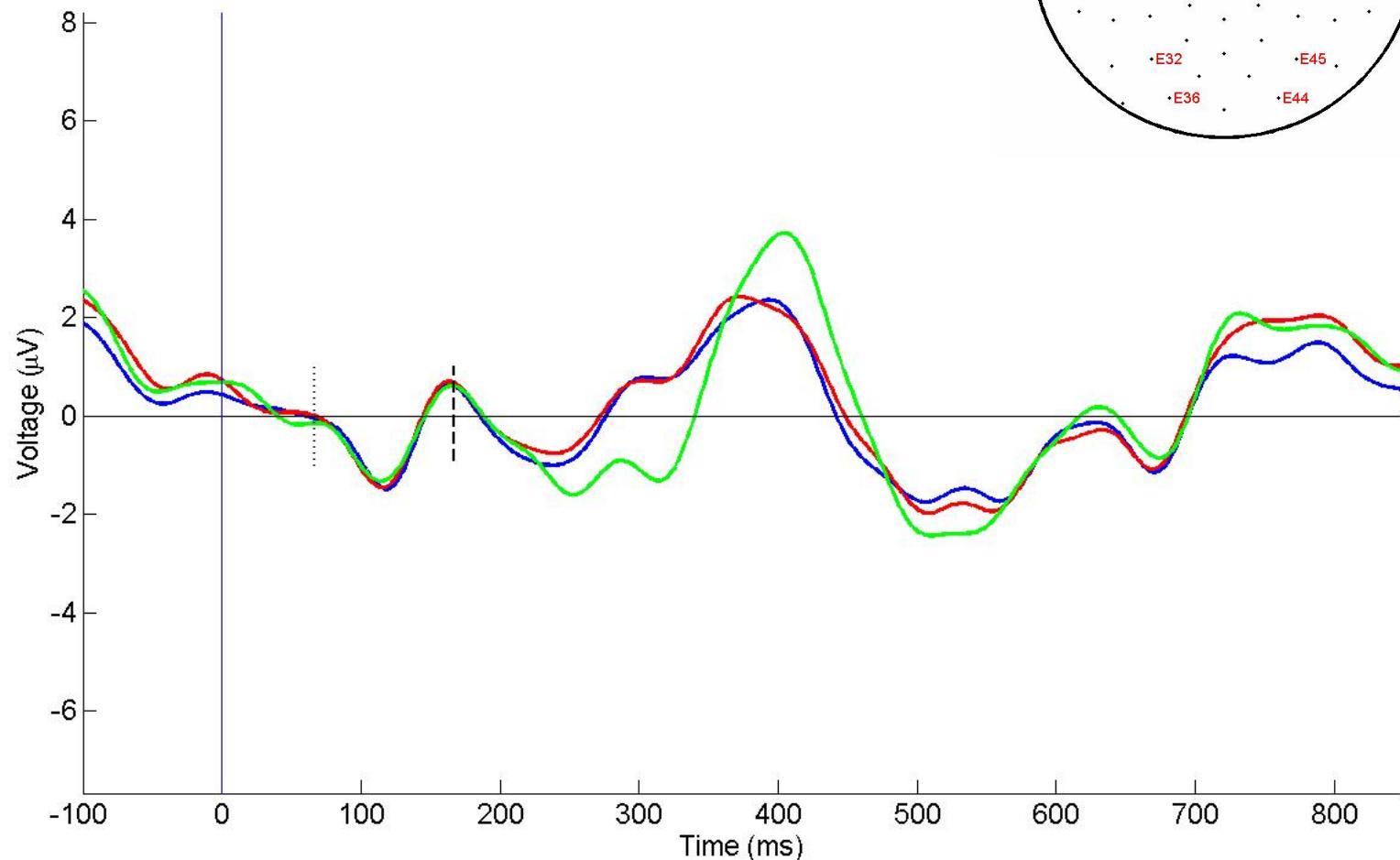


Channel locations

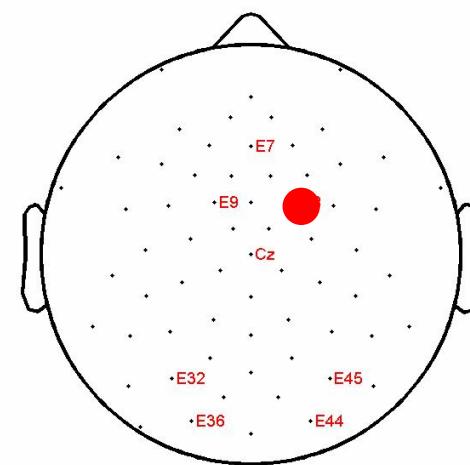


Anterior electrodes

- : Congruent
- : Incongruent
- : Blank

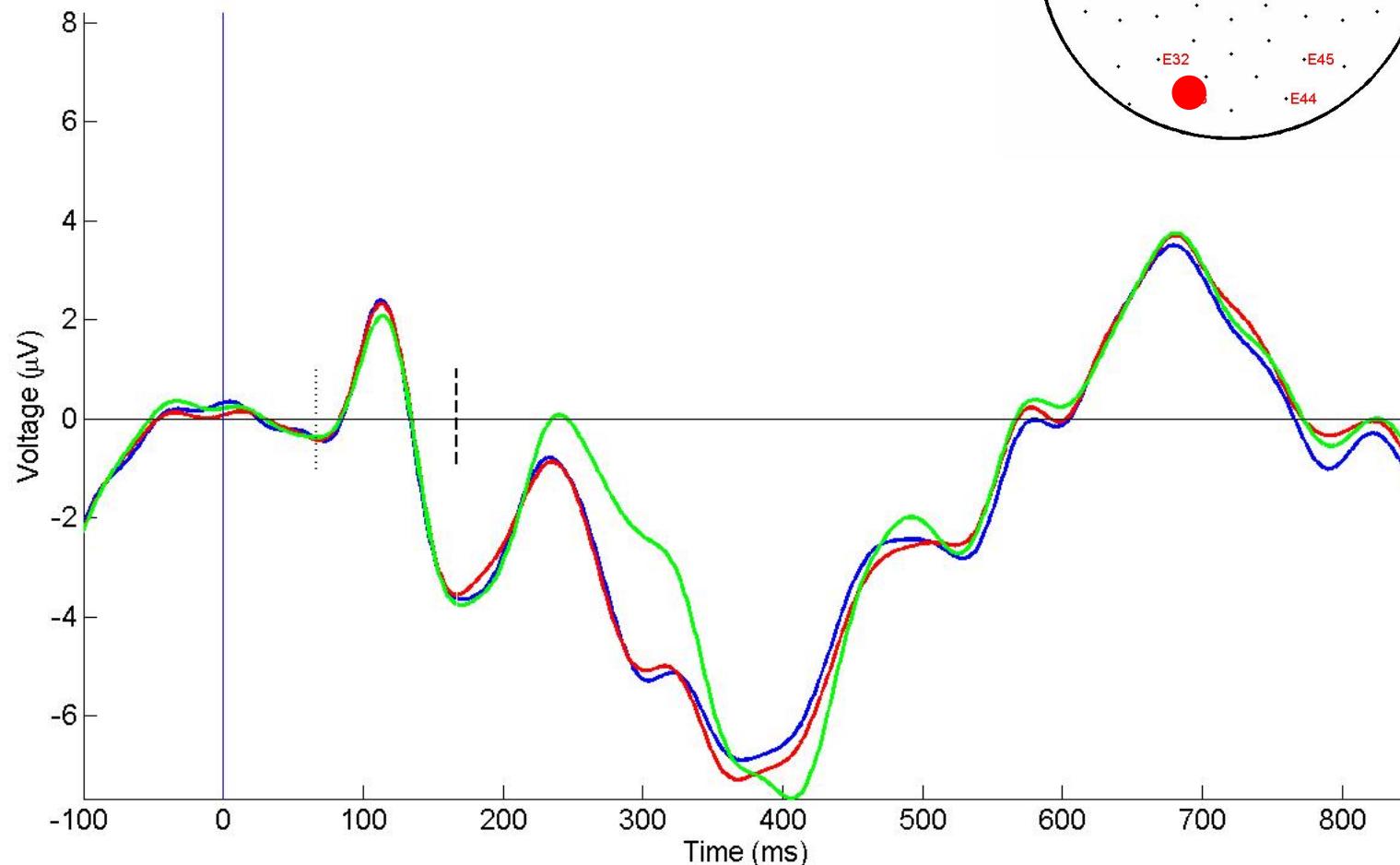


Channel locations

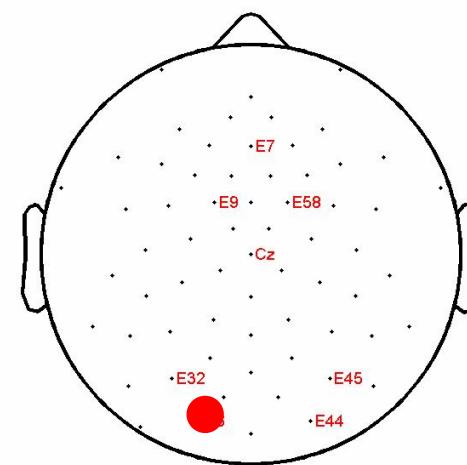


Posterior electrodes

- : Congruent
- : Incongruent
- : Blank

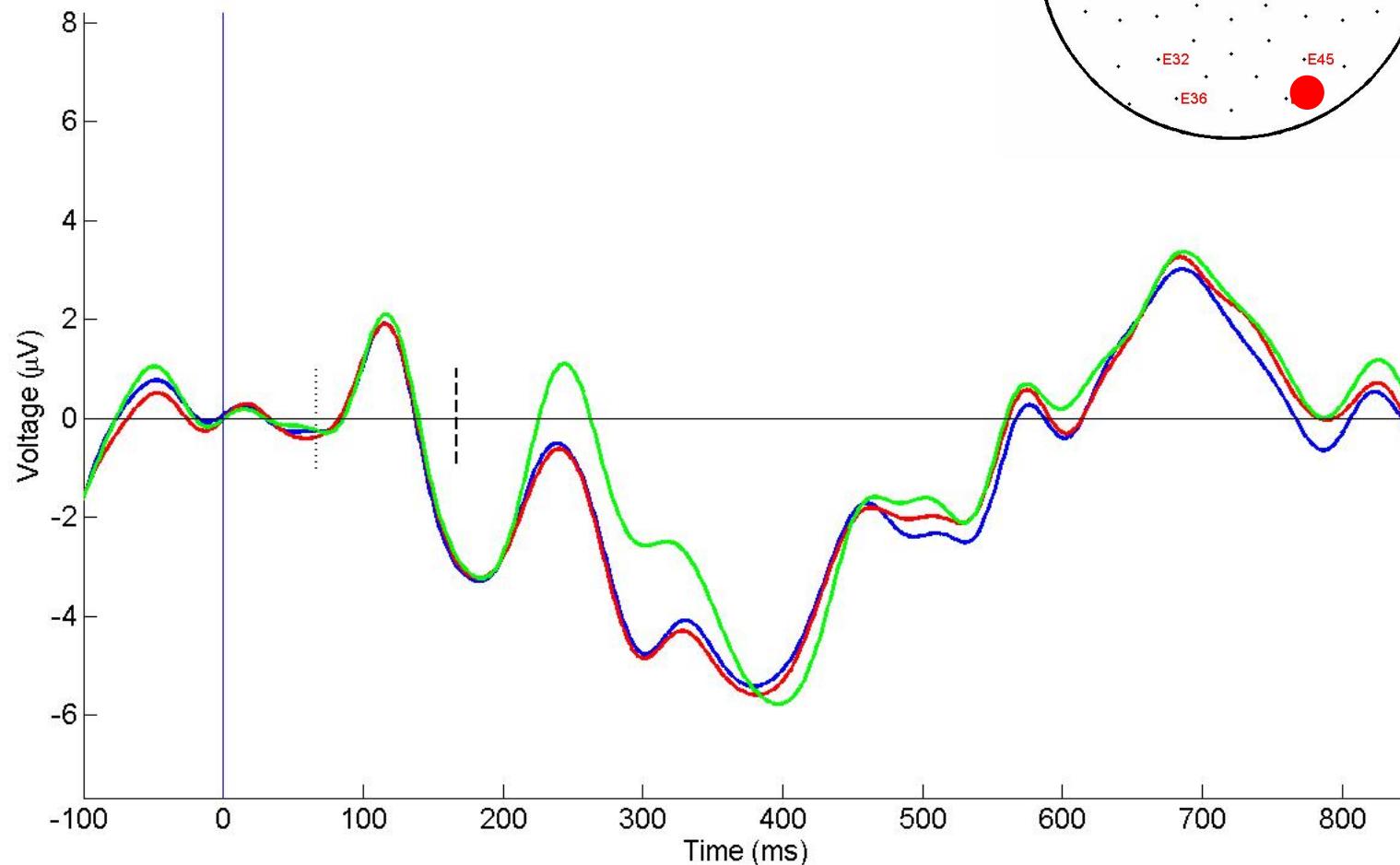


Channel locations

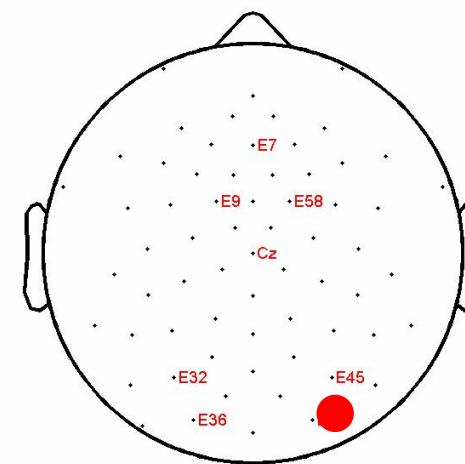


Posterior electrodes

----: Congruent
----: Incongruent
----: Blank



Channel locations



Conclusions

- Conscious processing of information correlates with transitory and early increments in long-distance synchronization
- Unconscious processing of information correlates with increments in local synchronization

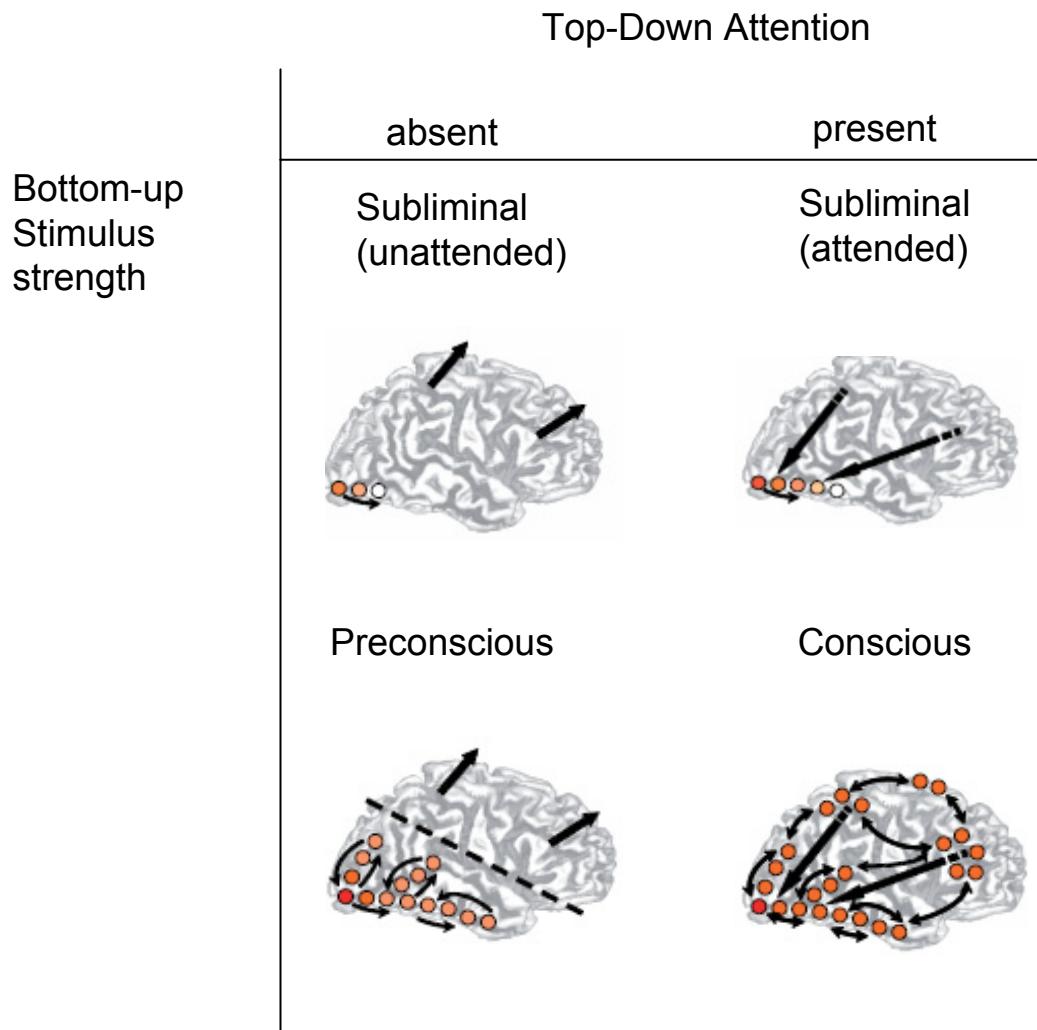
L1



Interaction between top-down and bottom-up: Hysteresis in conscious perception

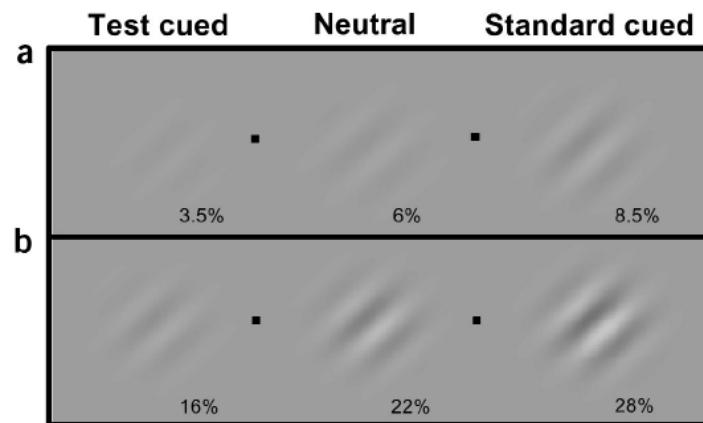
Neuronal global workspace theory of Consciousness

Stanislas Dehaene



One example: Attention alters appearance

Marisa Carrasco

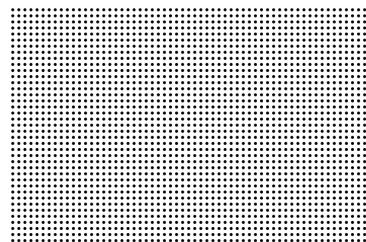


Can higher-order representation help in bringing a stimulus into perceptual awareness?

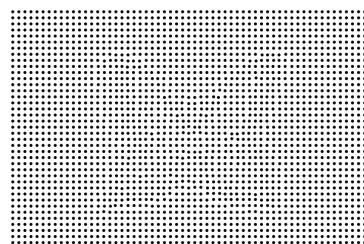


Conscious perception: Interplay between top-down and bottom-up

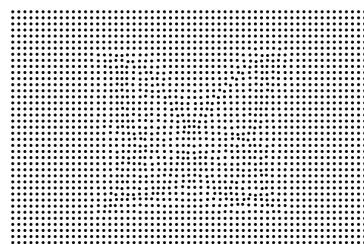
- How to study a phenomenon where top-down has a clear impact in bottom-up processing?: **Hysteresis effect**
 - Hysteresis typically occurs in visual perception.
 - In general there seems to be a tendency for something already perceived to continue to be perceived and for something not yet perceived to remain unperceived. This tendency towards perceptual inertia is called **HYSTERESIS**.
 - Hysteresis is a property of systems that do not instantly follow the forces applied to them, but to react slowly, or do not return completely to their original state. That is, systems whose states depend on their immediate history.



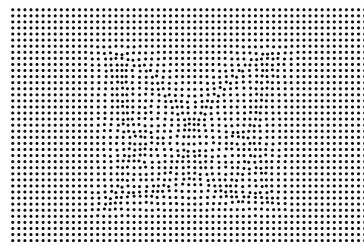
S1



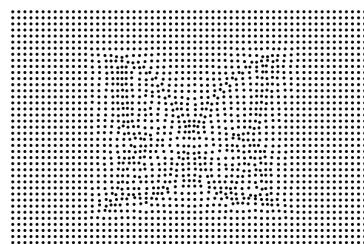
S2



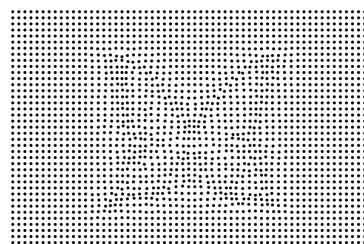
S3



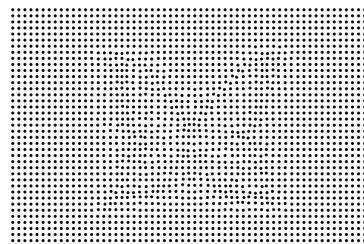
S4



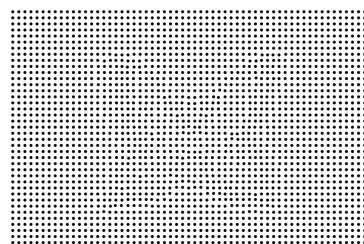
S5



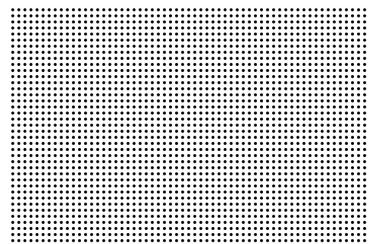
S4



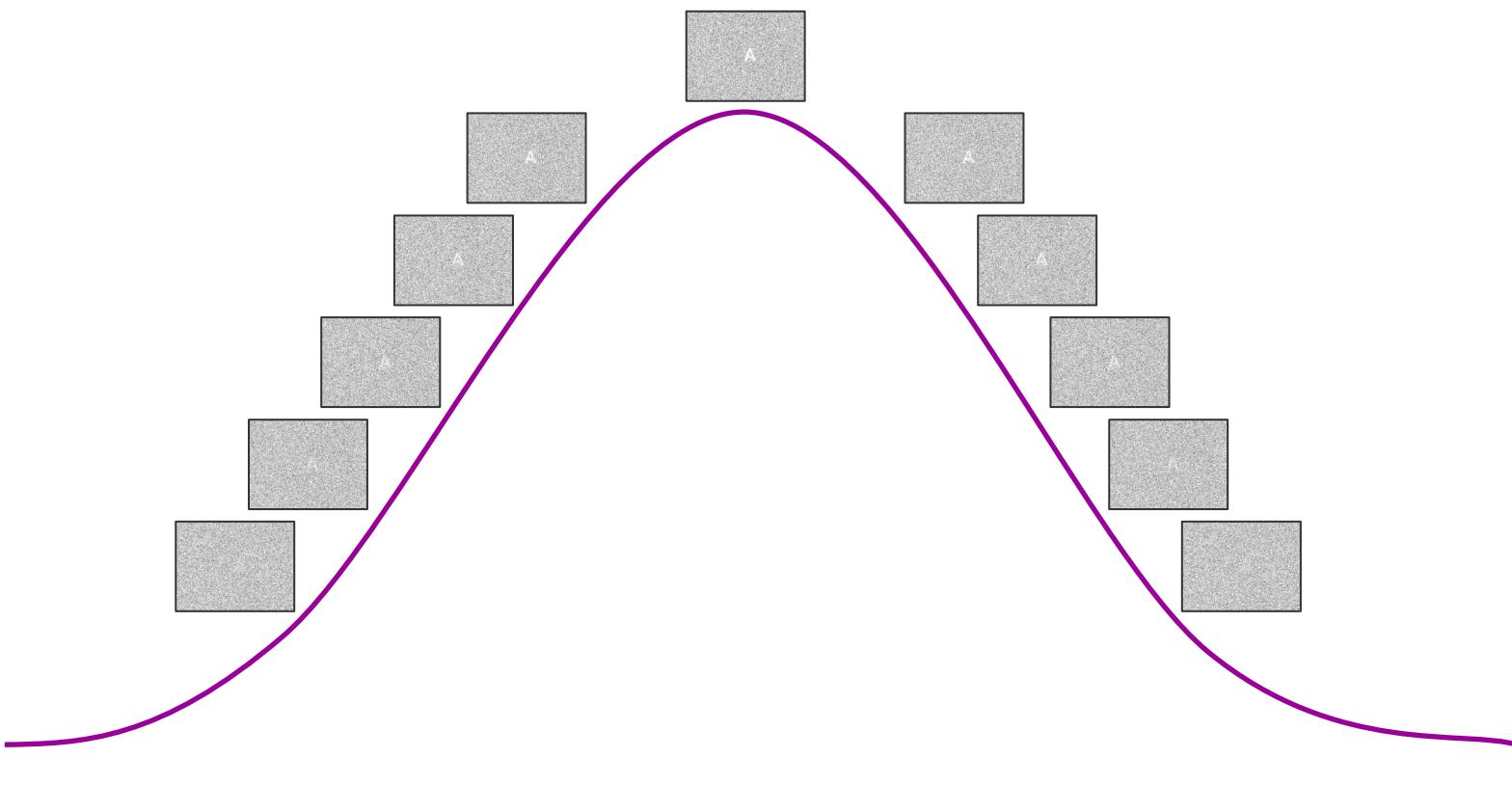
S3



S2



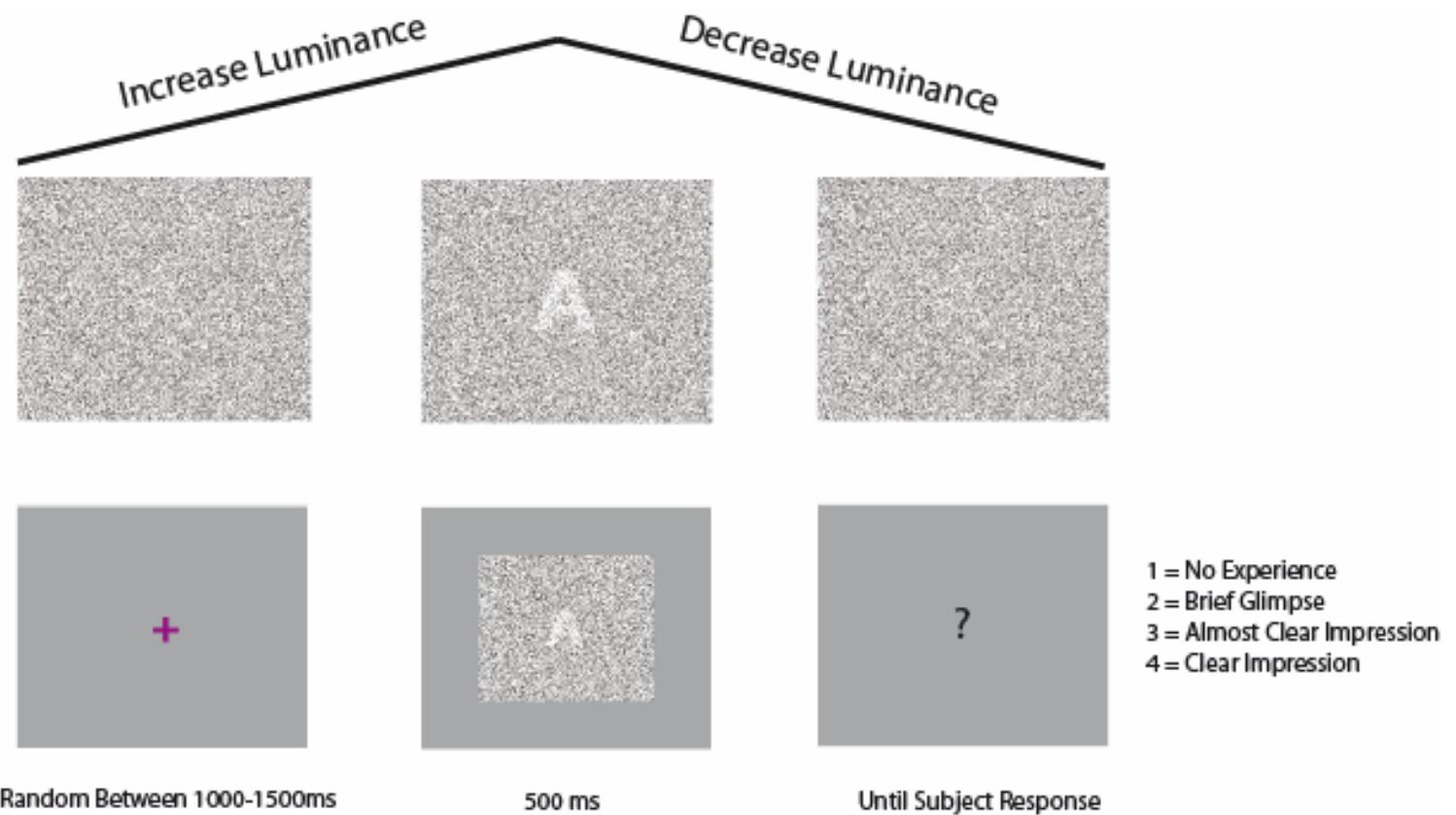
S1



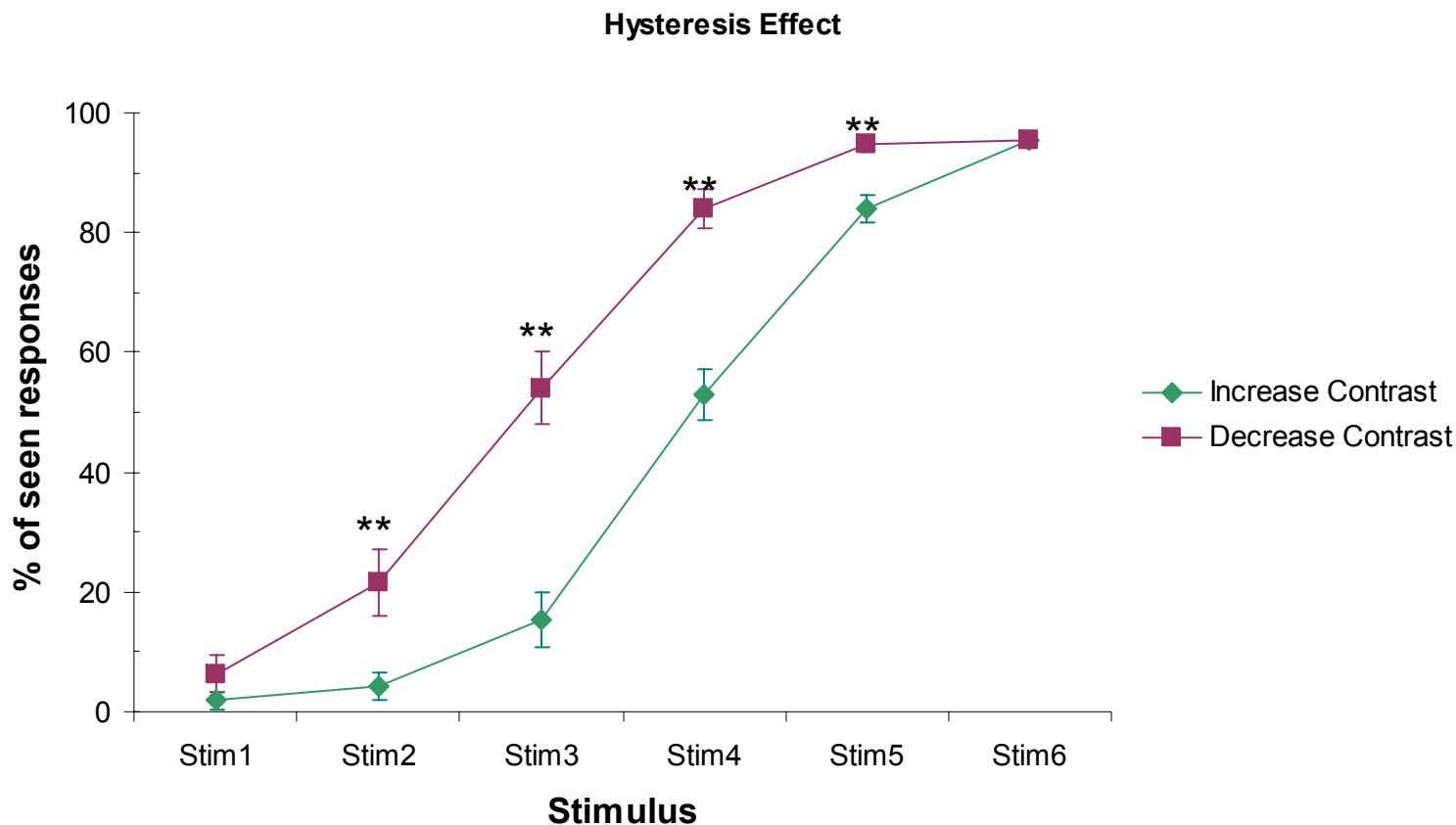
Bottom-up

Bottom-up + Top Down

EXPERIMENTAL DESIGN



Behavioral results: Hysteresis Effect

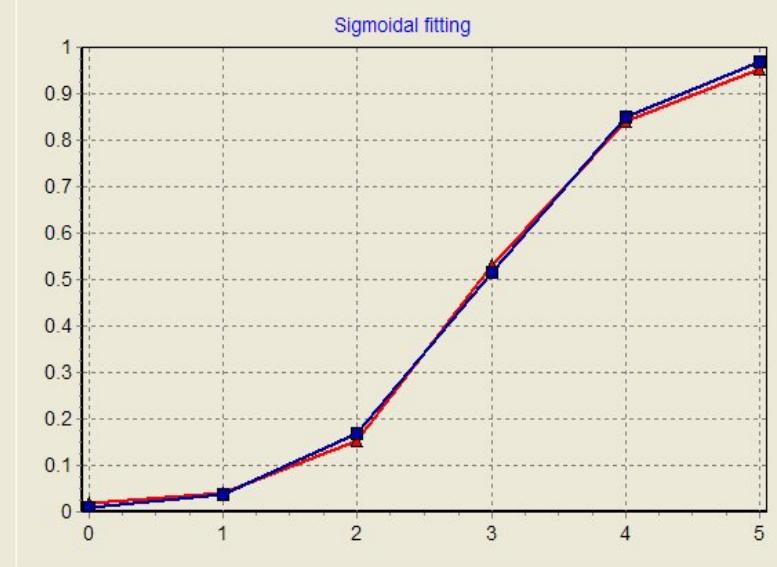


Scale 2: 1+2: Unseen
3+4: Seen

N=16 subjects
** : $p < .005$

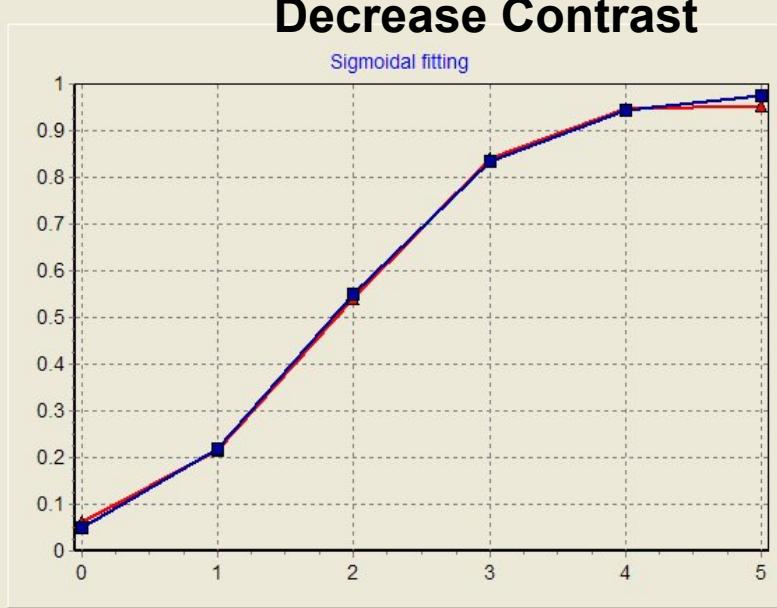
Behavioral results: Hysteresis Effect

Increase Contrast



a = 1.6716
b = 0.0024
f_i = 3.9669
Fit error = 0.0009

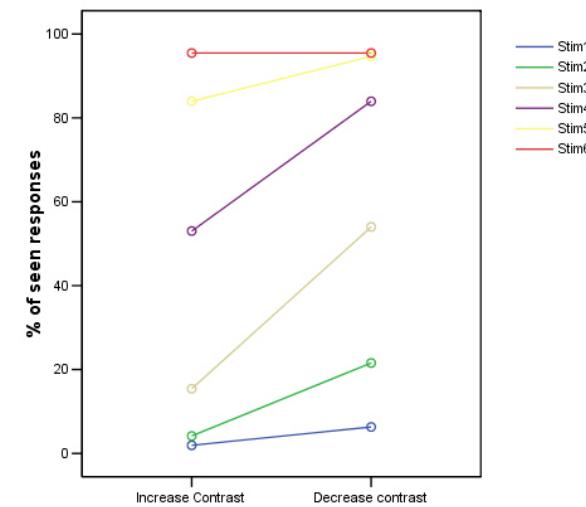
Decrease Contrast



a = 1.4588
b = -0.0154
f_i = 2.8157
Fit error = 0.0007

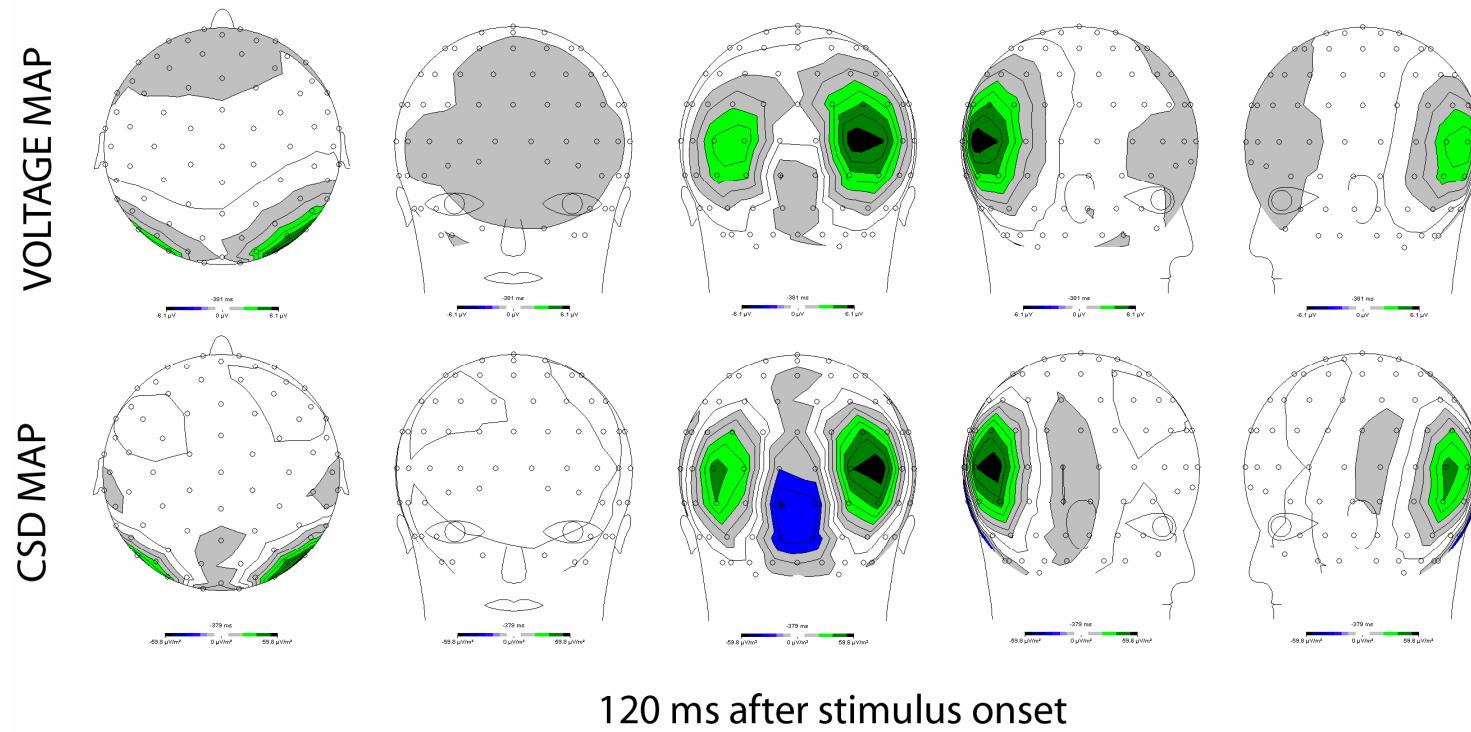
	Up	Down
a	1.6716	1.4588
b	0.0024	-0.0154
y	3.9669	2.8157
Shift	1.1512	

$$F(x) = \frac{1}{1 + e^{-a(x-y)}} + b$$

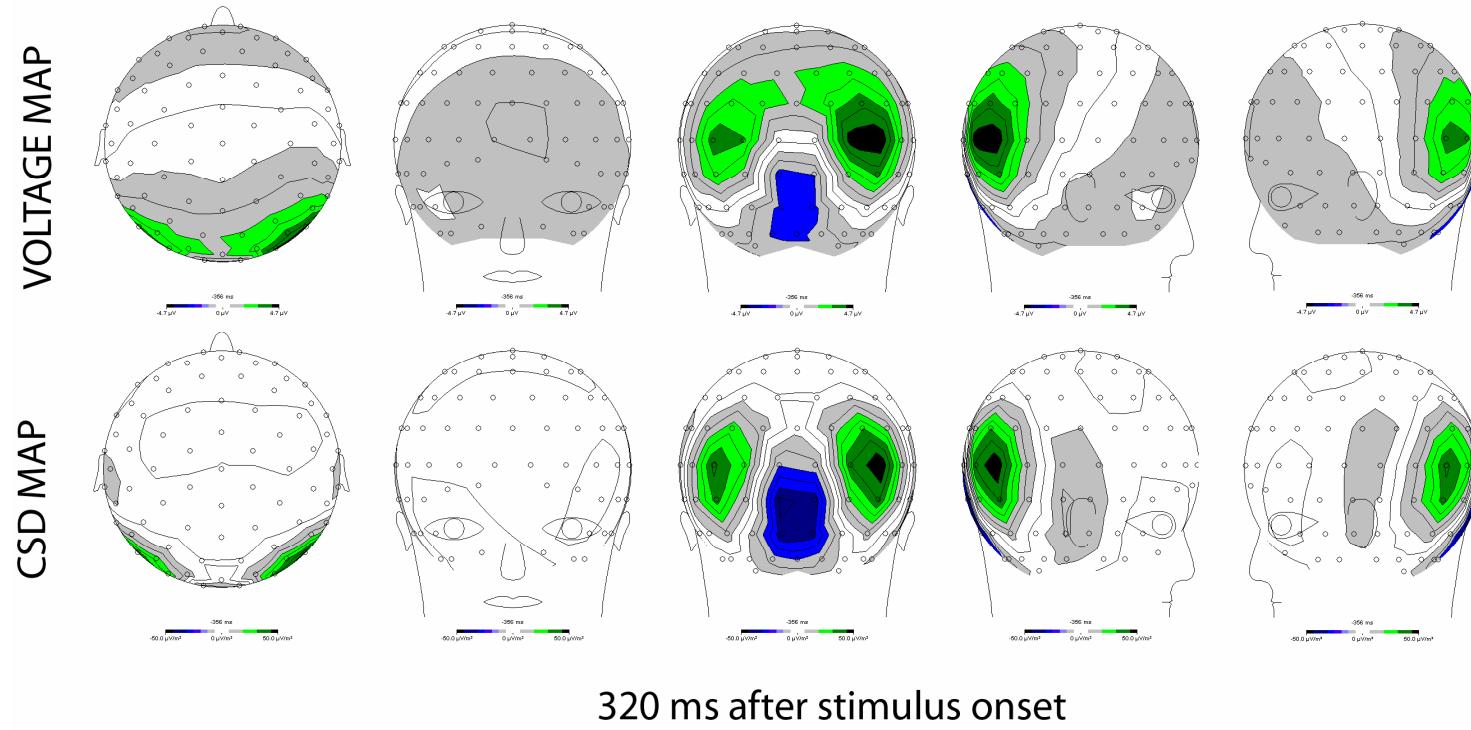


N=16 subjects

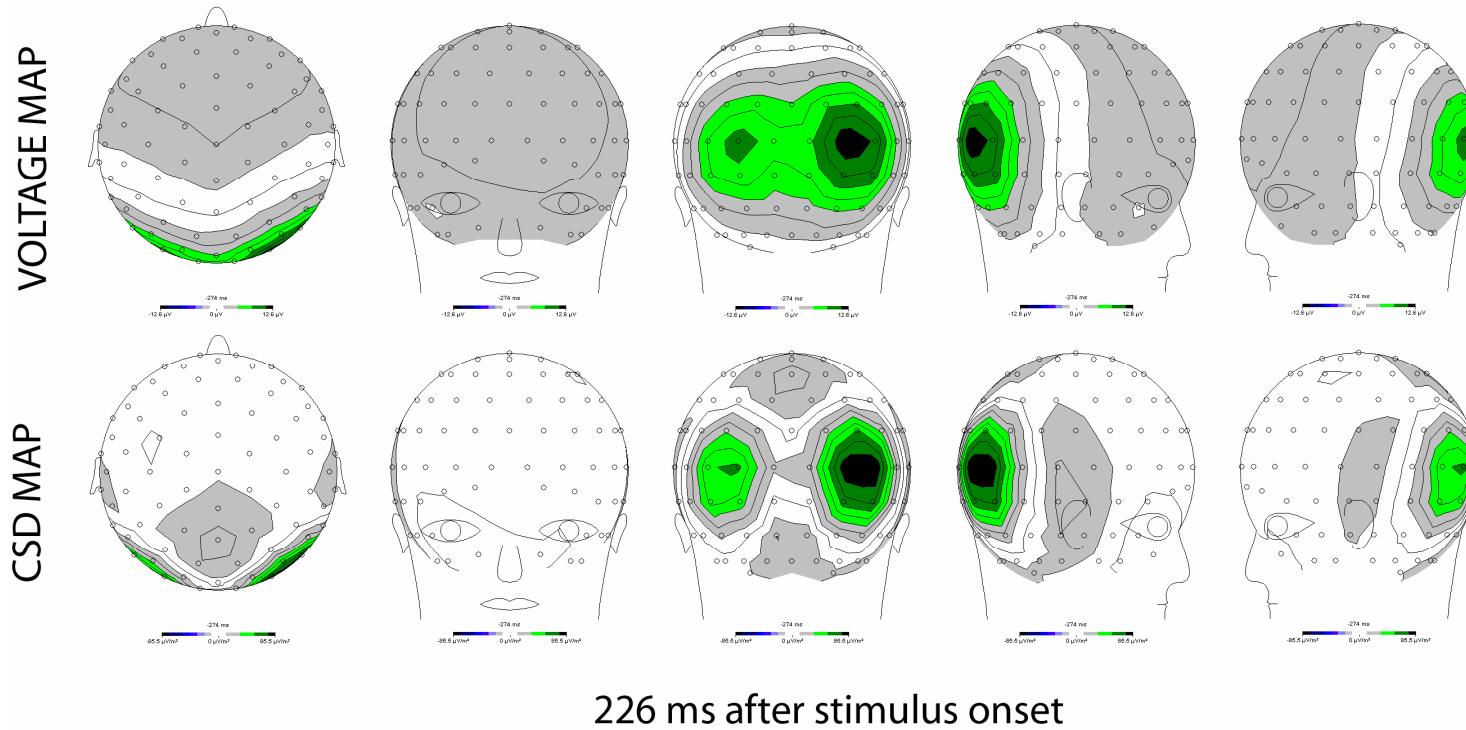
ERPs results: P100



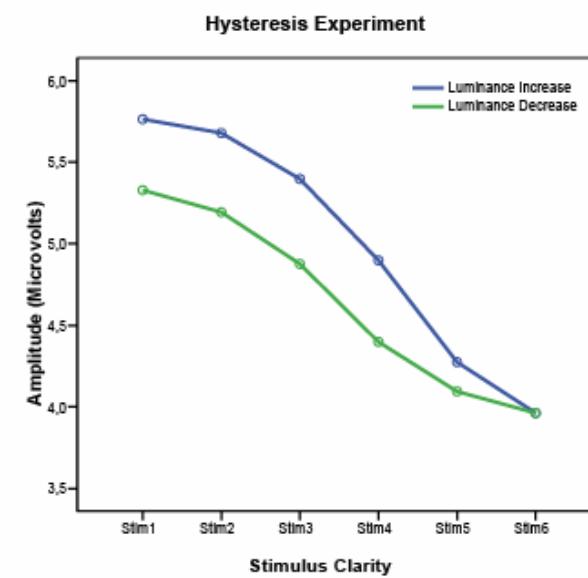
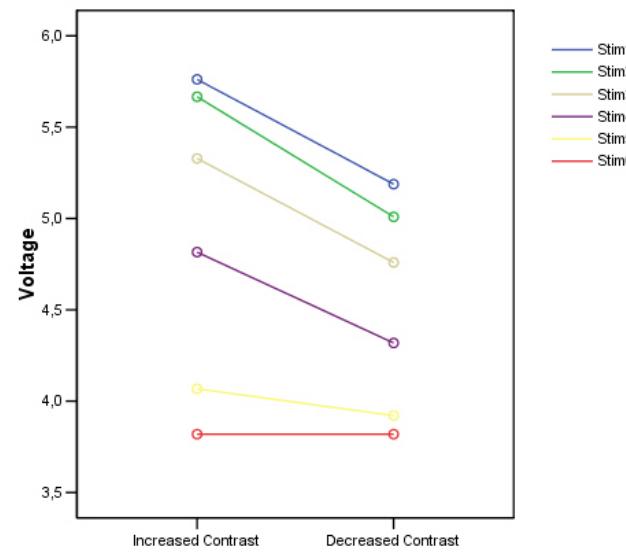
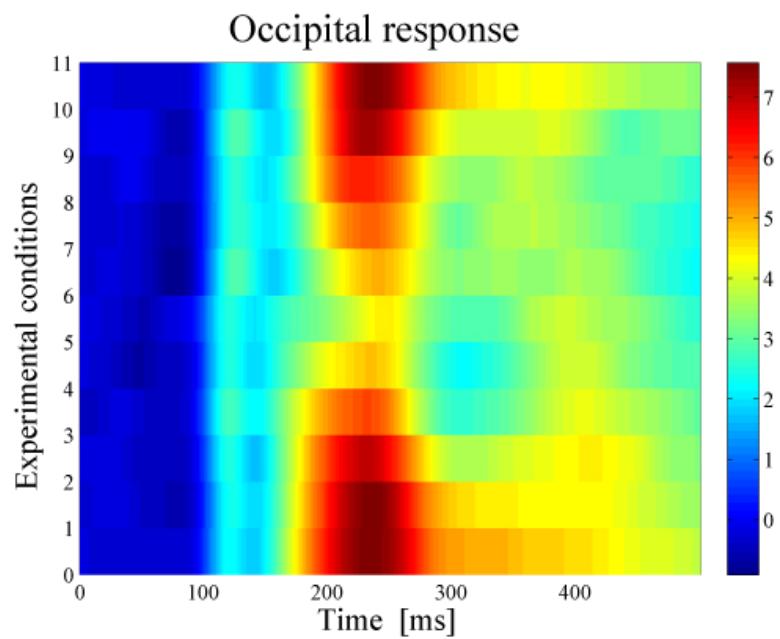
ERPs results: N100



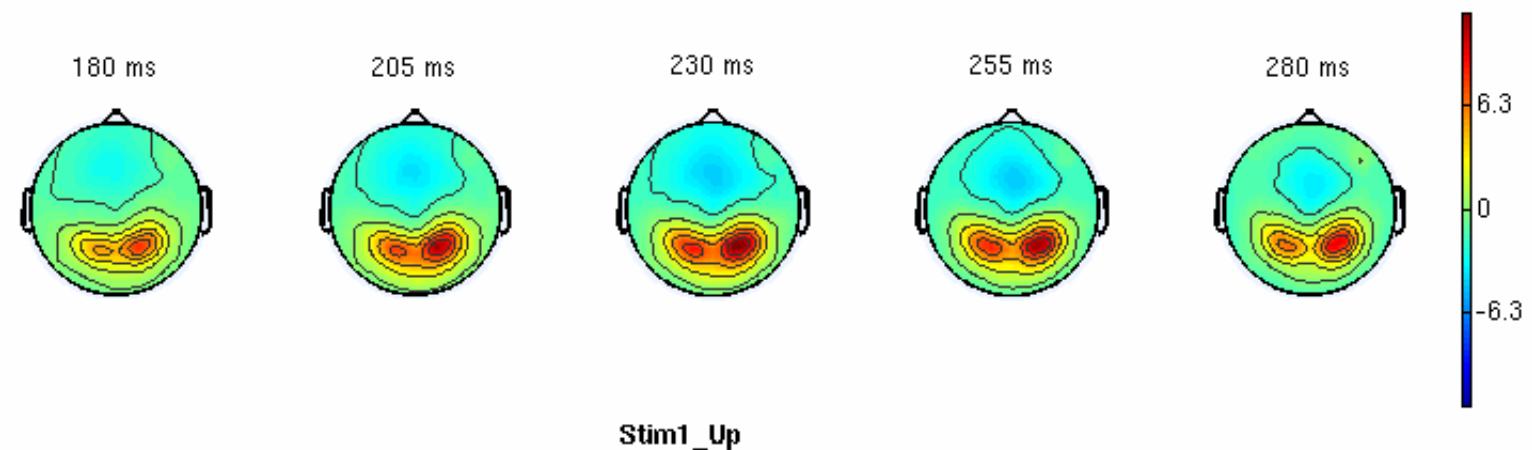
ERPs results: P200



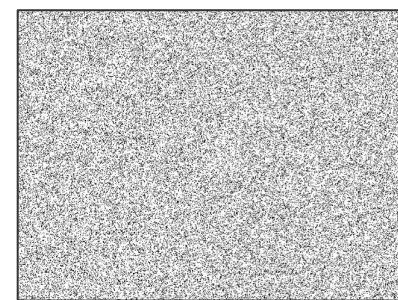
ERP's results: Hysteresis Effect (P200)



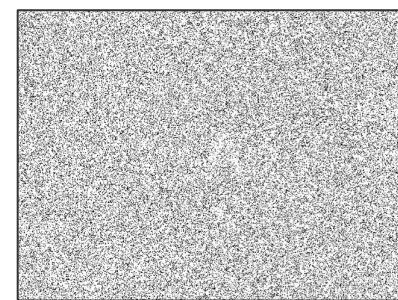
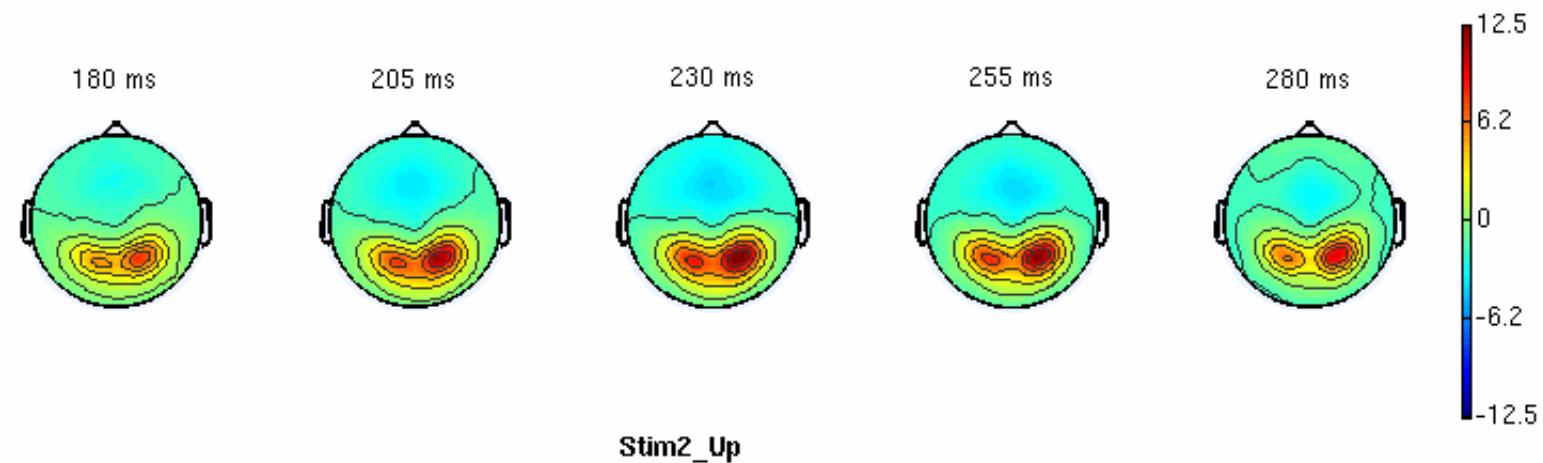
ERPs results: Hysteresis Effect (P200 topography)



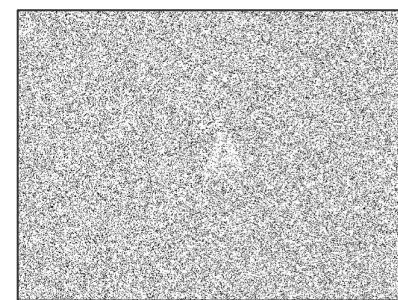
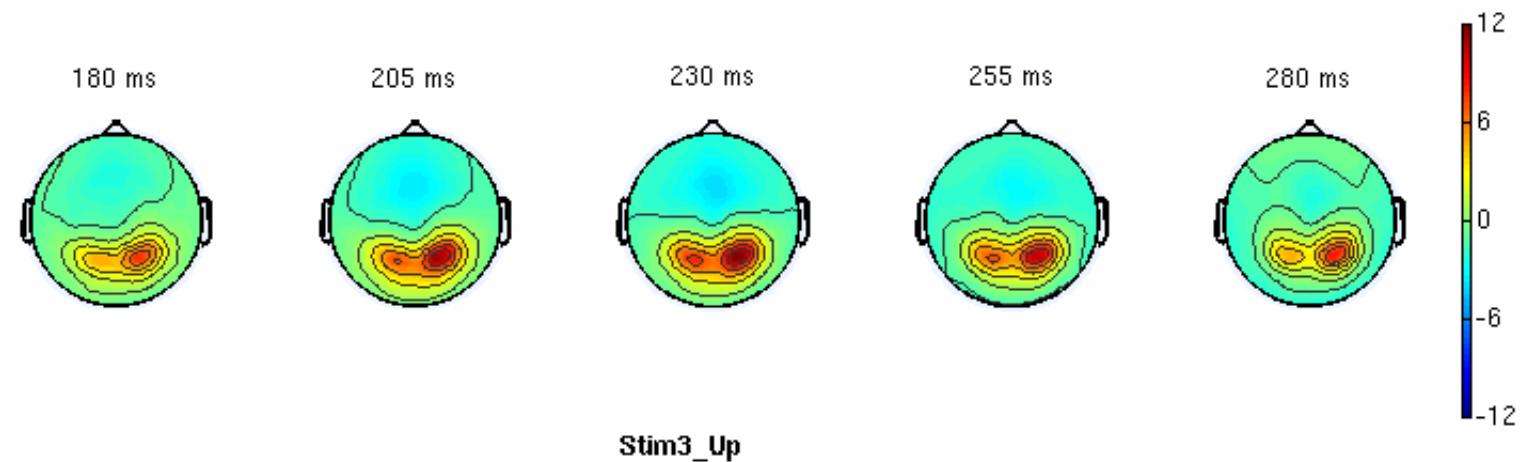
Stim1_Up



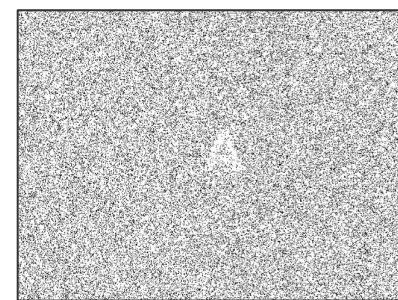
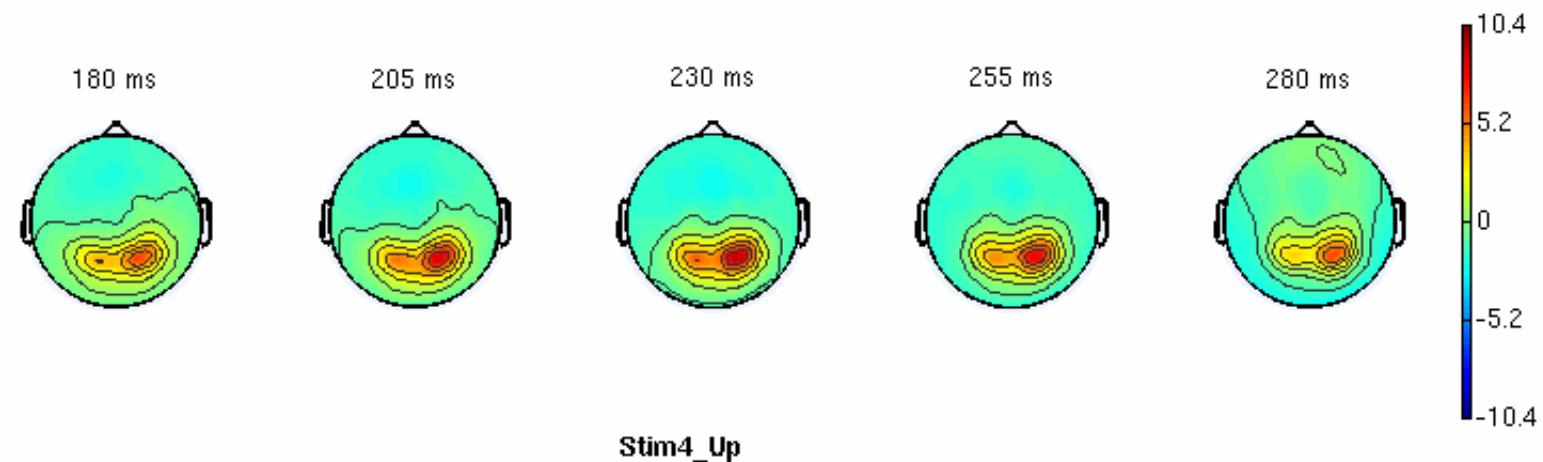
ERPs results: Hysteresis Effect (P200 topography)



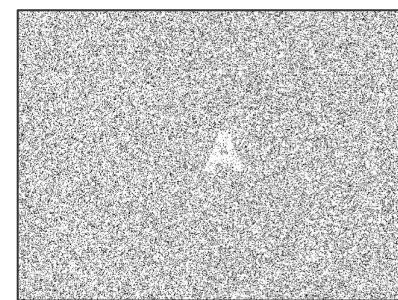
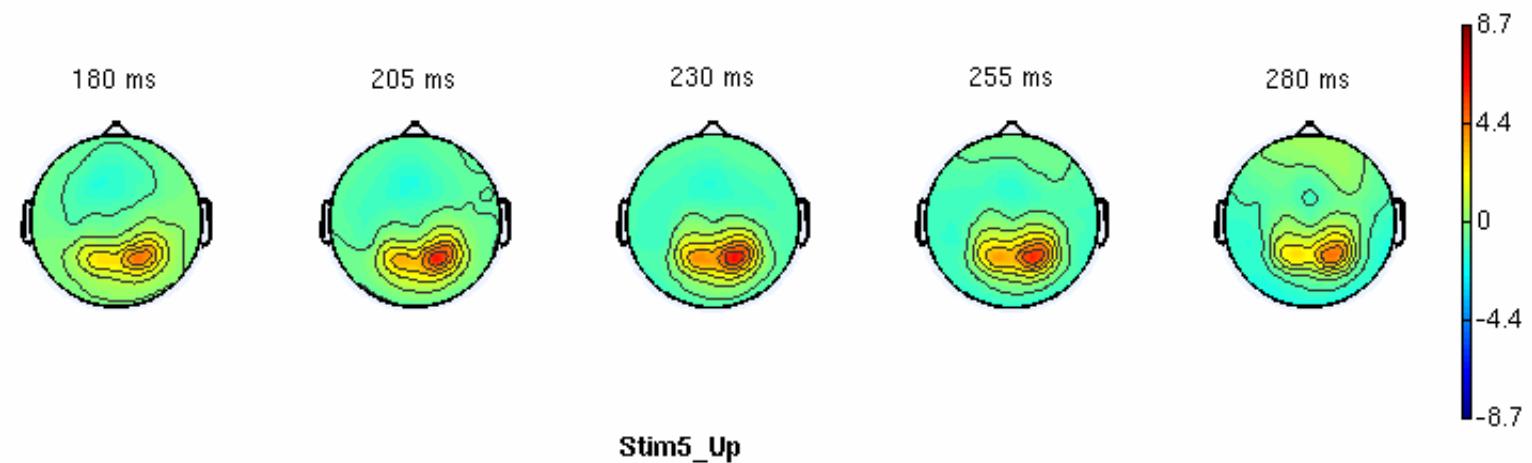
ERPs results: Hysteresis Effect (P200 topography)



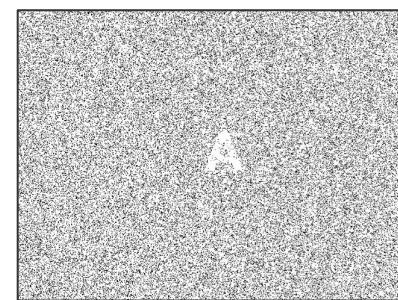
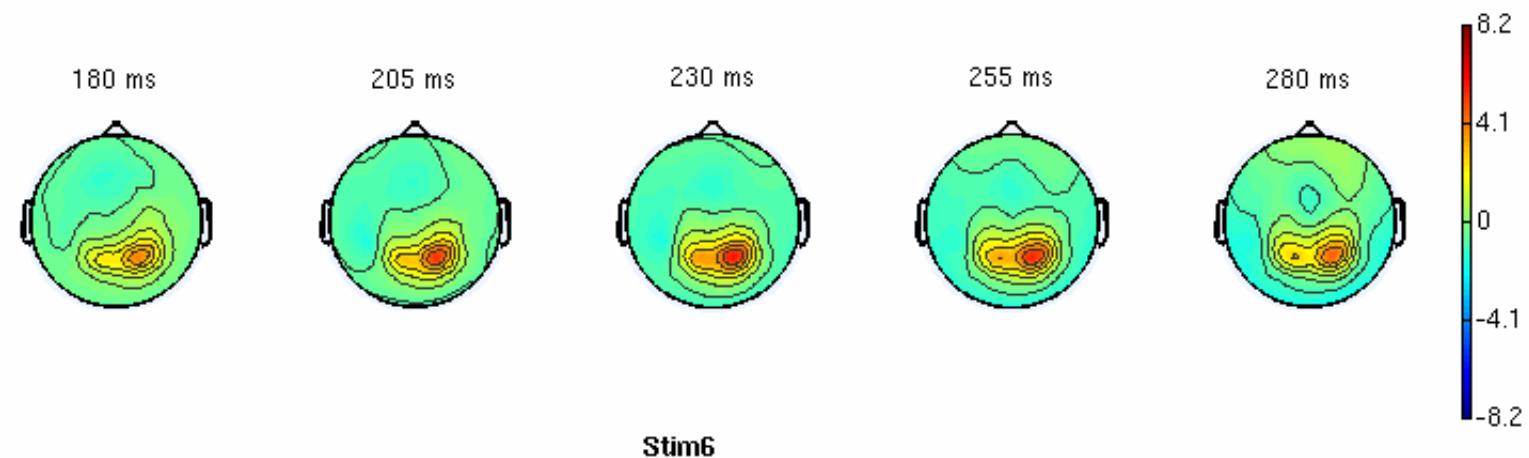
ERPs results: Hysteresis Effect (P200 topography)



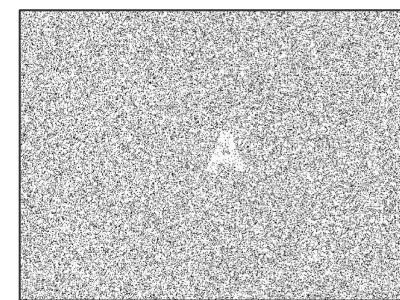
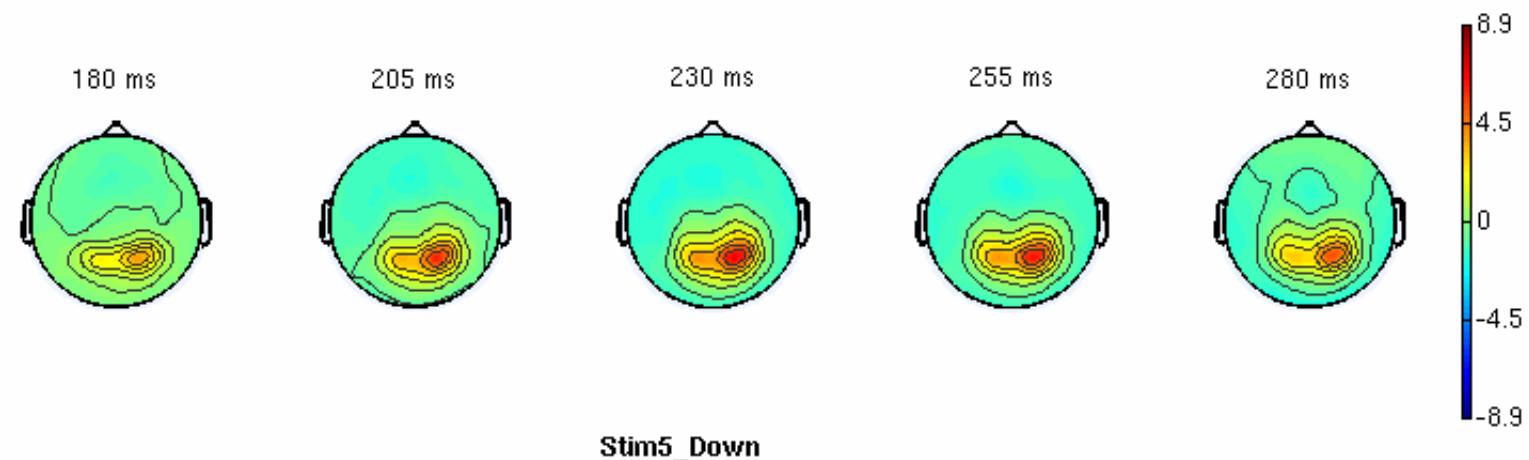
ERPs results: Hysteresis Effect (P200 topography)



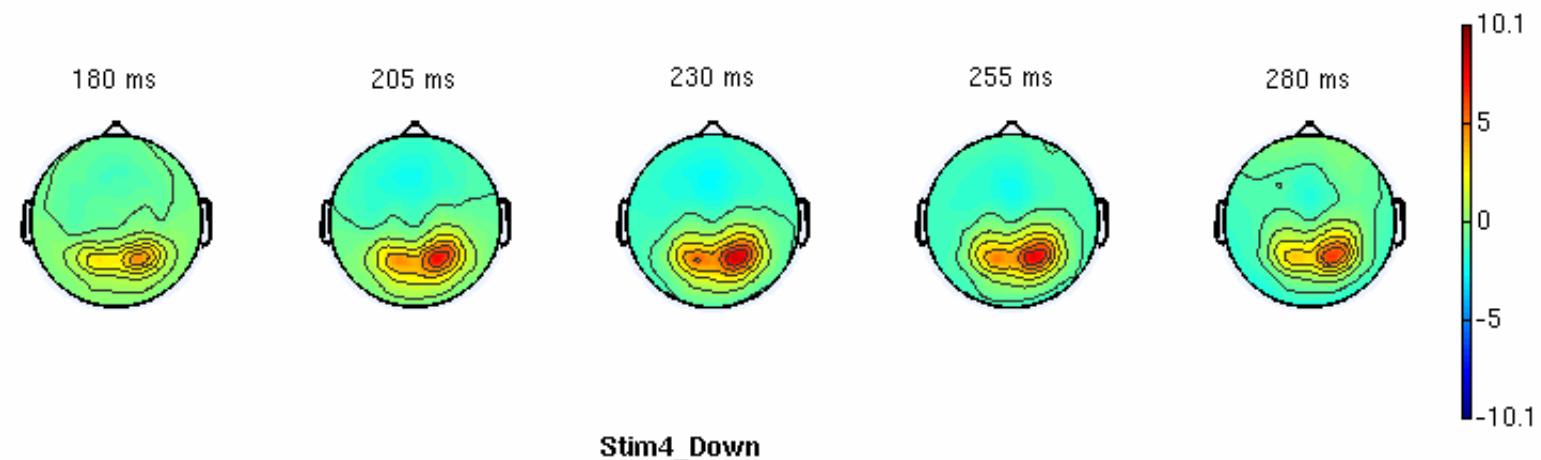
ERPs results: Hysteresis Effect (P200 topography)



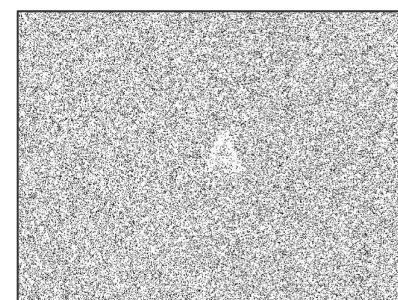
ERPs results: Hysteresis Effect (P200 topography)



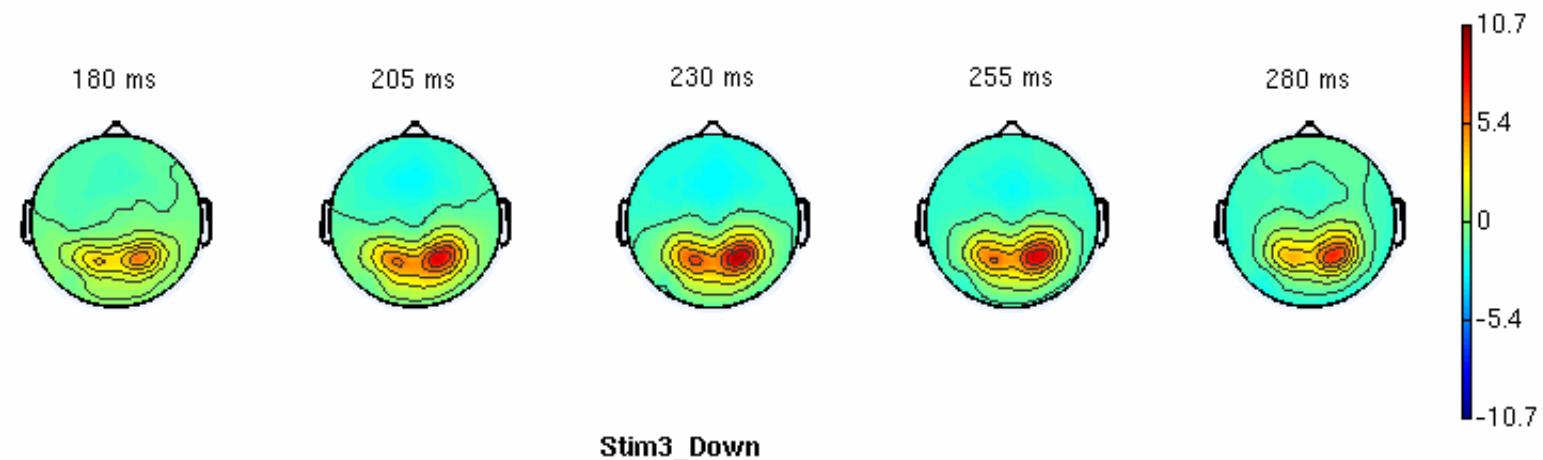
ERPs results: Hysteresis Effect (P200 topography)



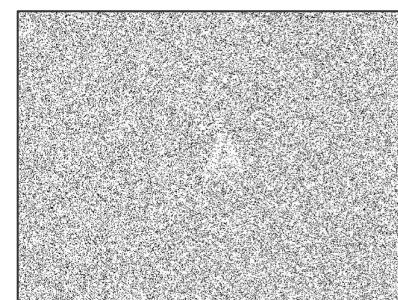
Stim4_Down



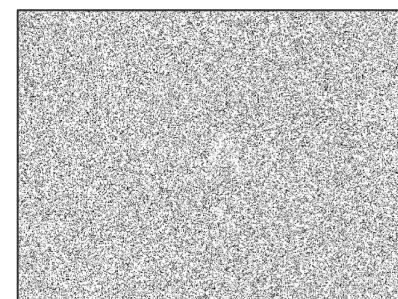
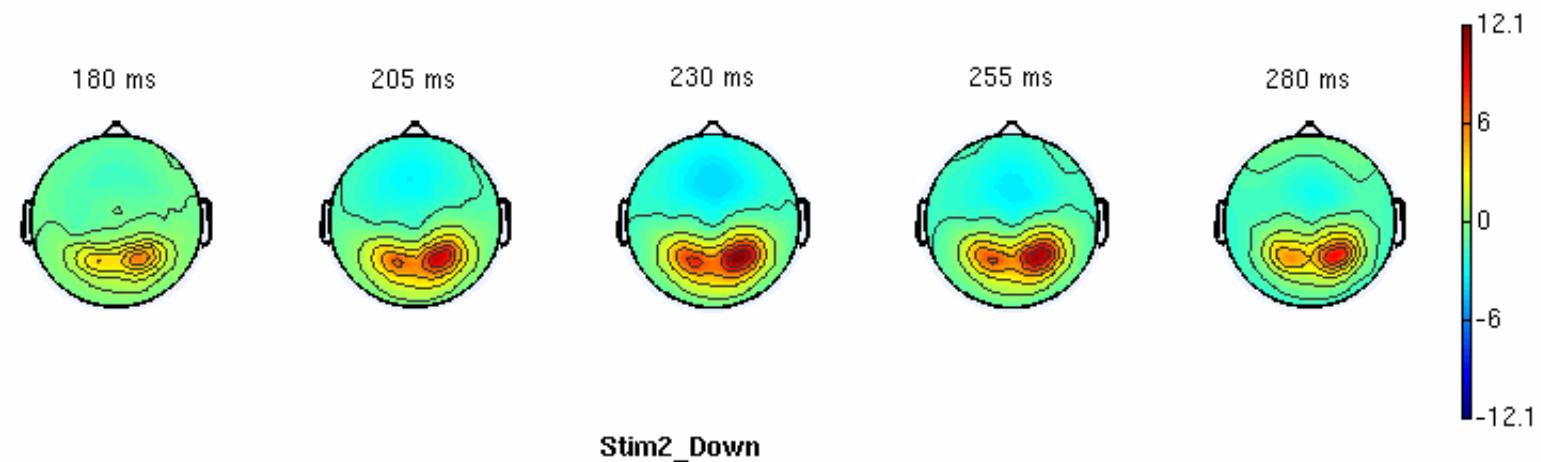
ERPs results: Hysteresis Effect (P200 topography)



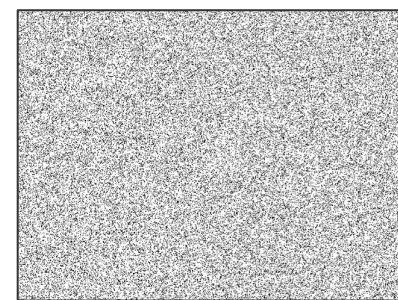
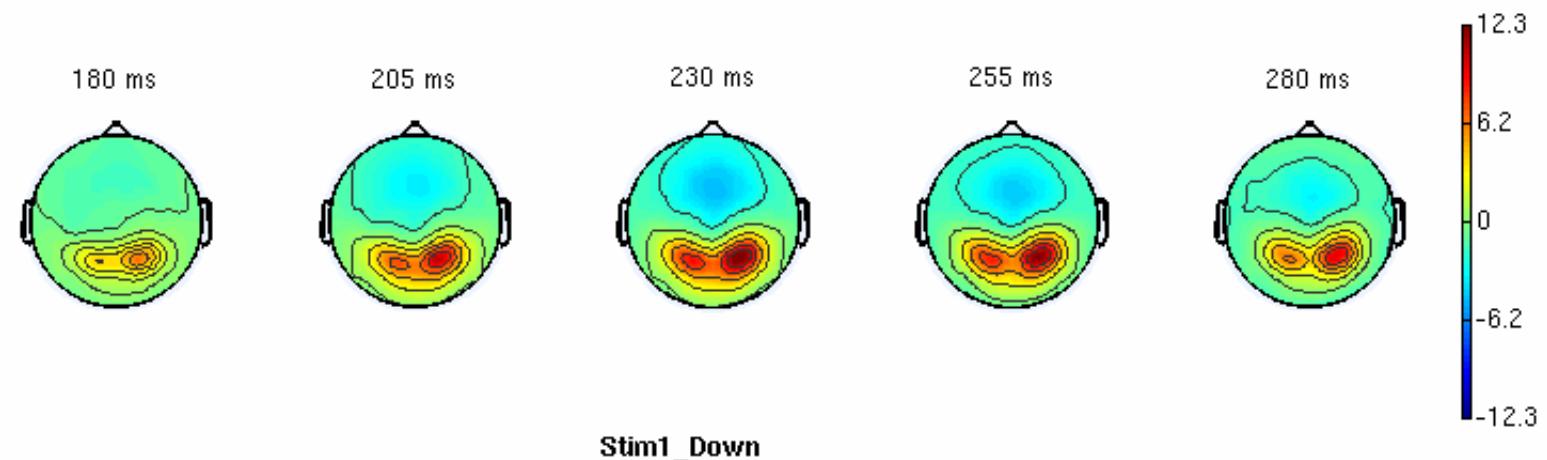
Stim3_Down



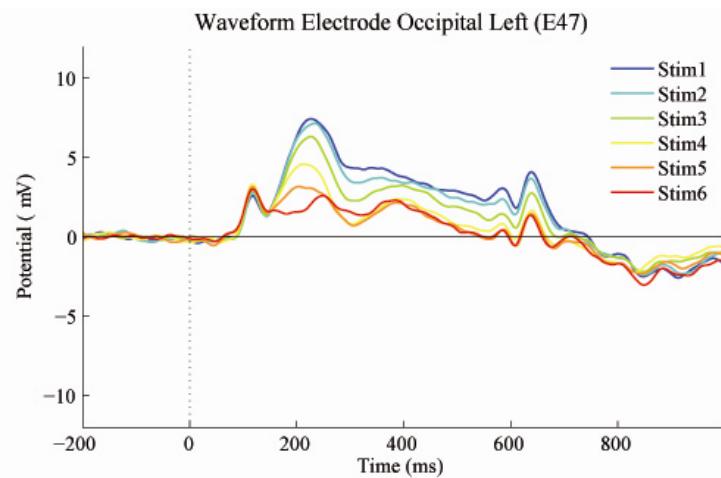
ERPs results: Hysteresis Effect (P200 topography)



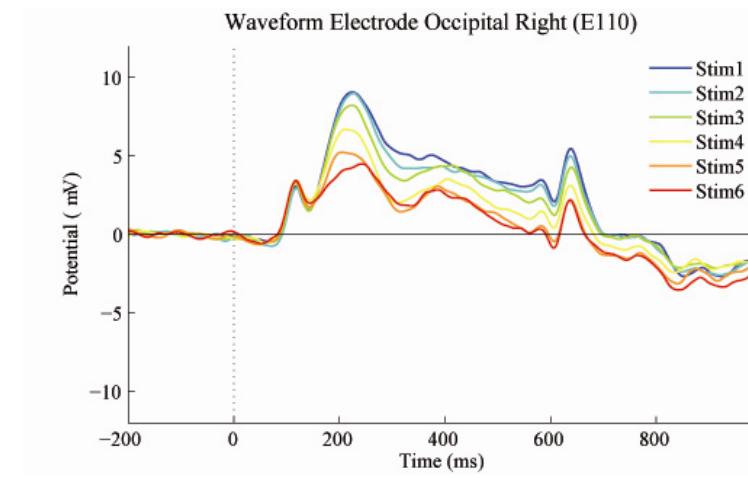
ERPs results: Hysteresis Effect (P200 topography)



ERPs results: Hysteresis Effect

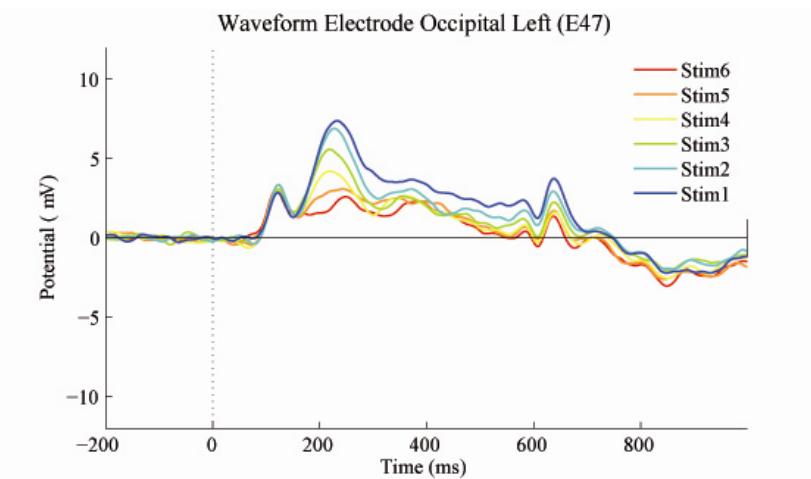


Contrast Increase

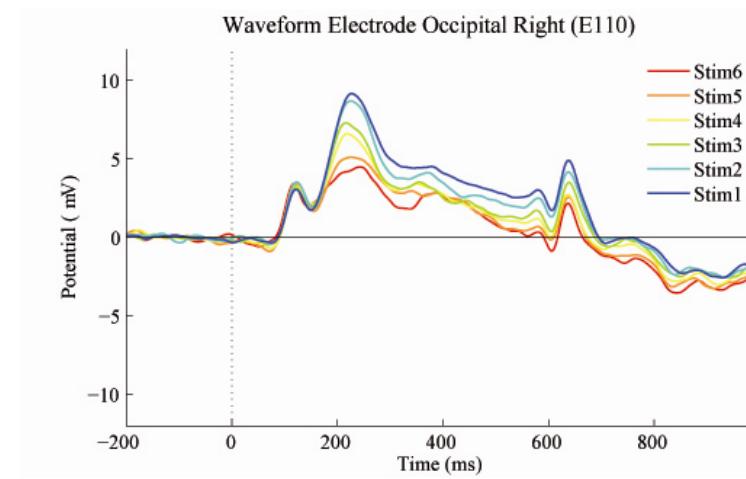


Contrast Increase

ERPs results: Hysteresis Effect

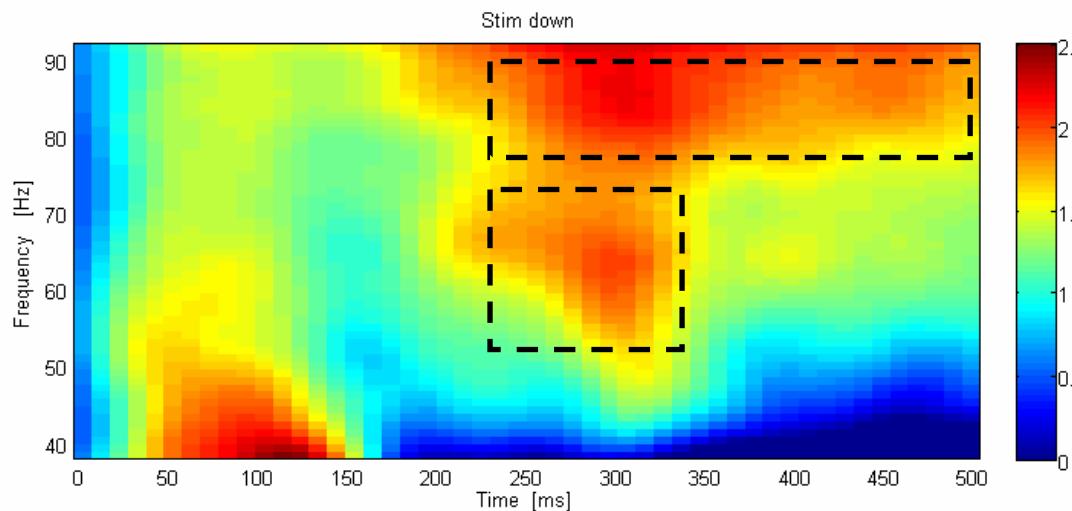
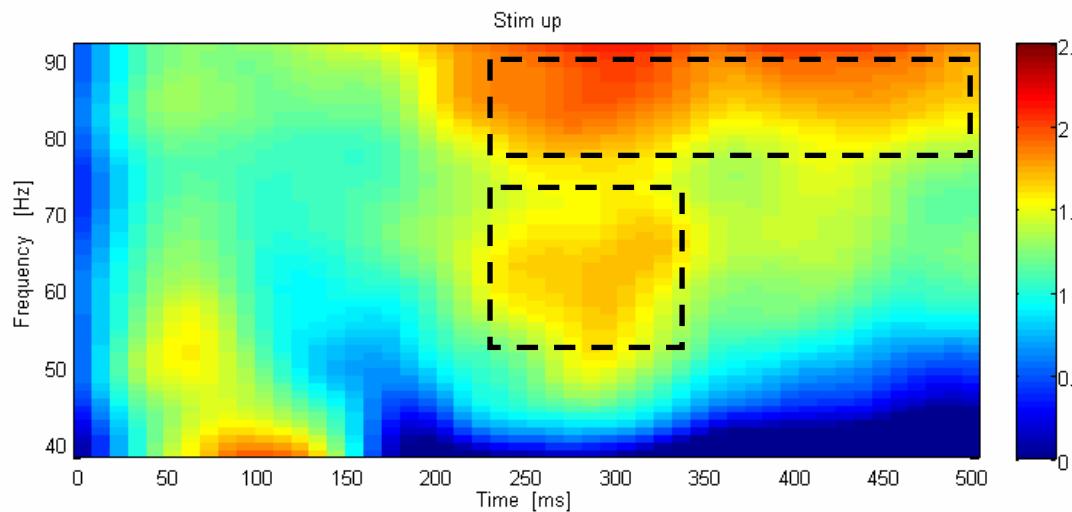


Contrast Decrease

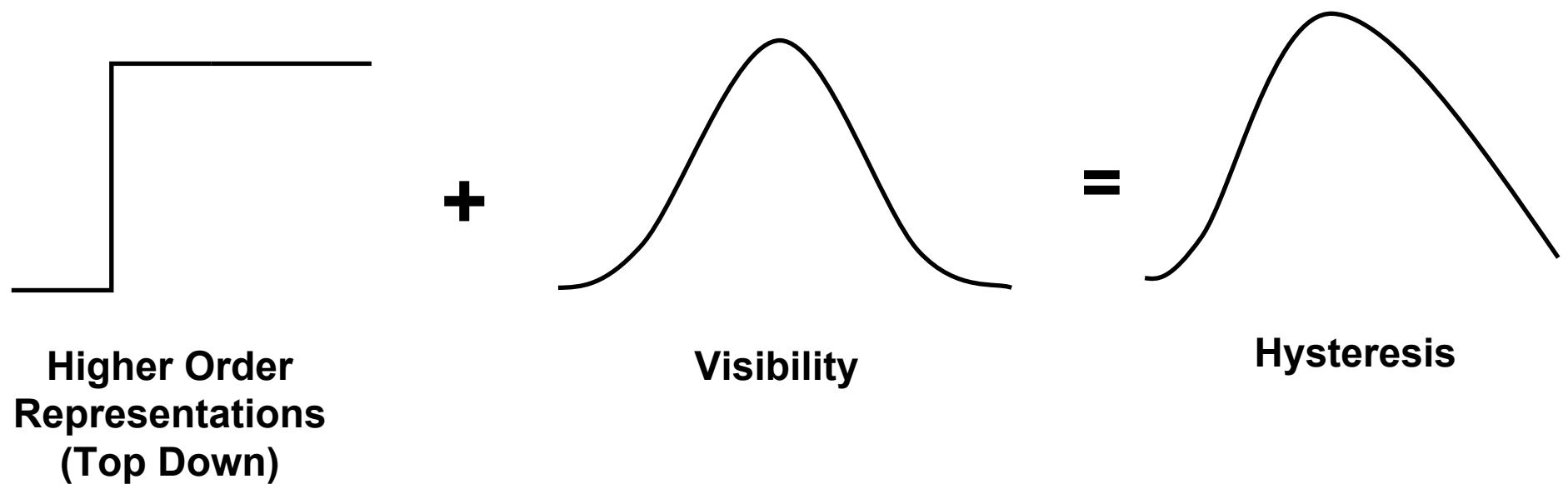


Contrast Decrease

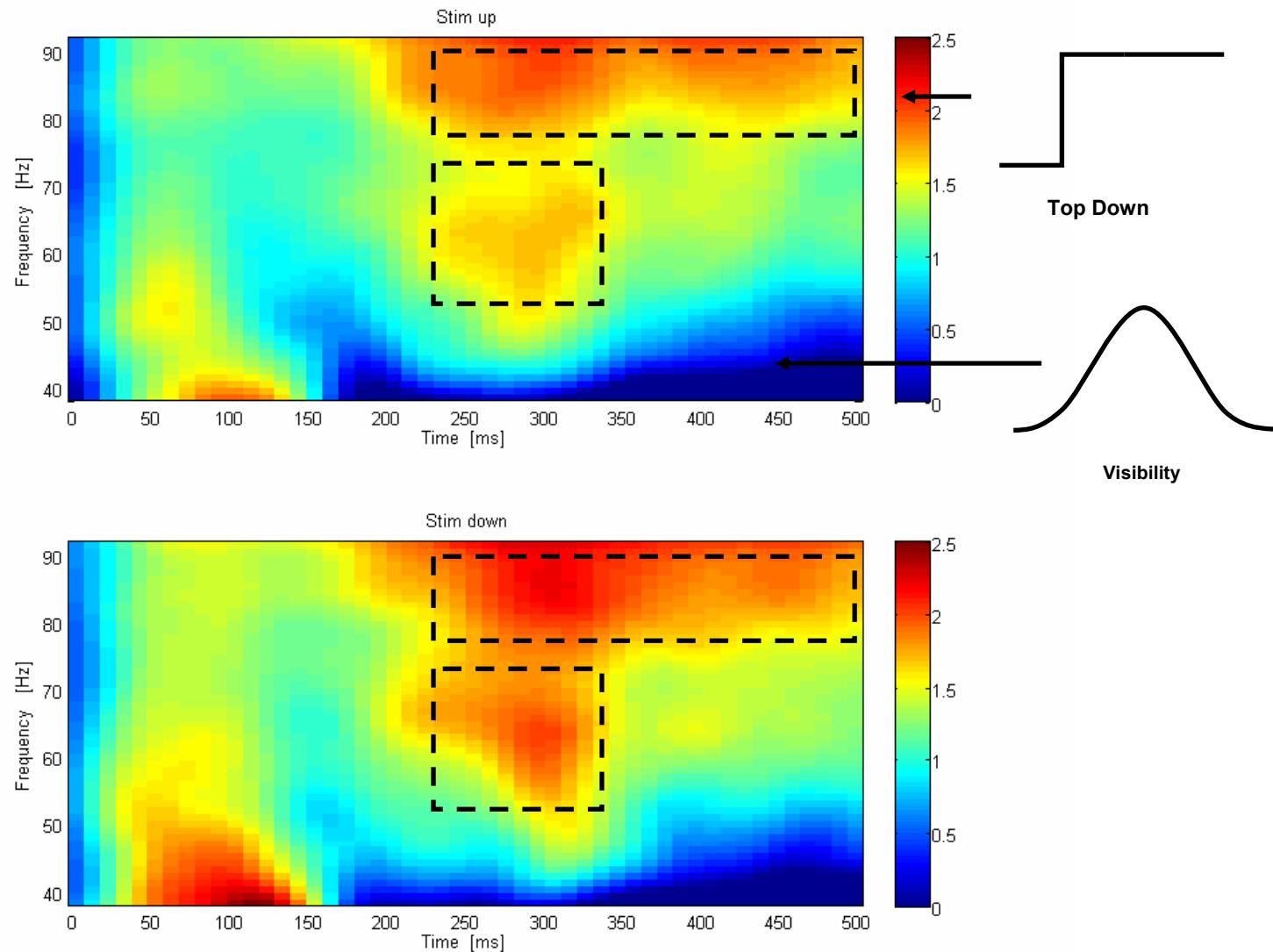
Induced Gamma Response: Hysteresis Effect



How can perceptual hysteresis arise?

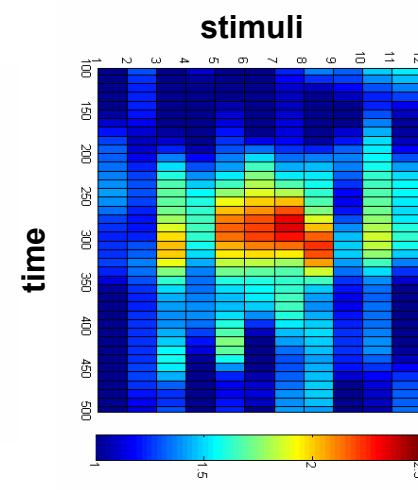
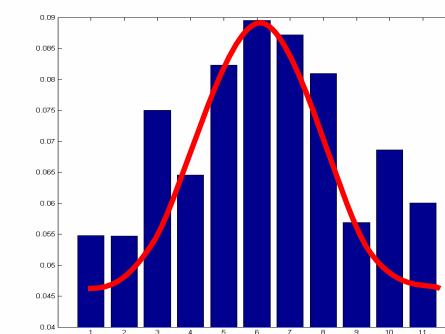
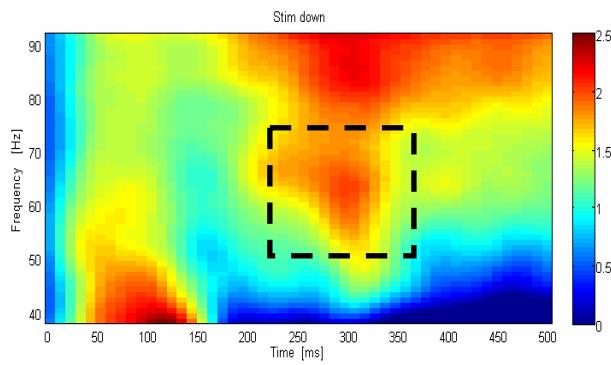
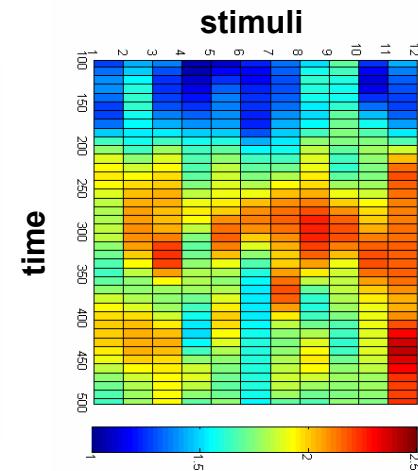
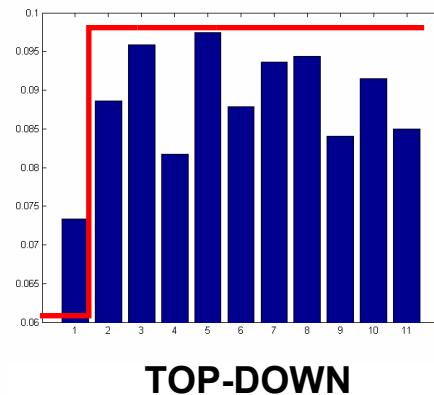
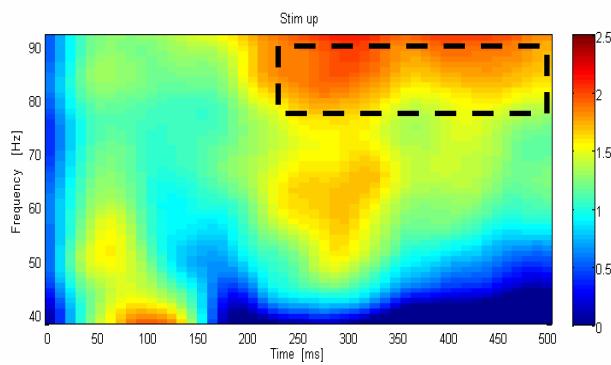


Can responses in different frequencies explain the hysteresis effect?



Can responses in different frequencies explain the hysteresis effect?

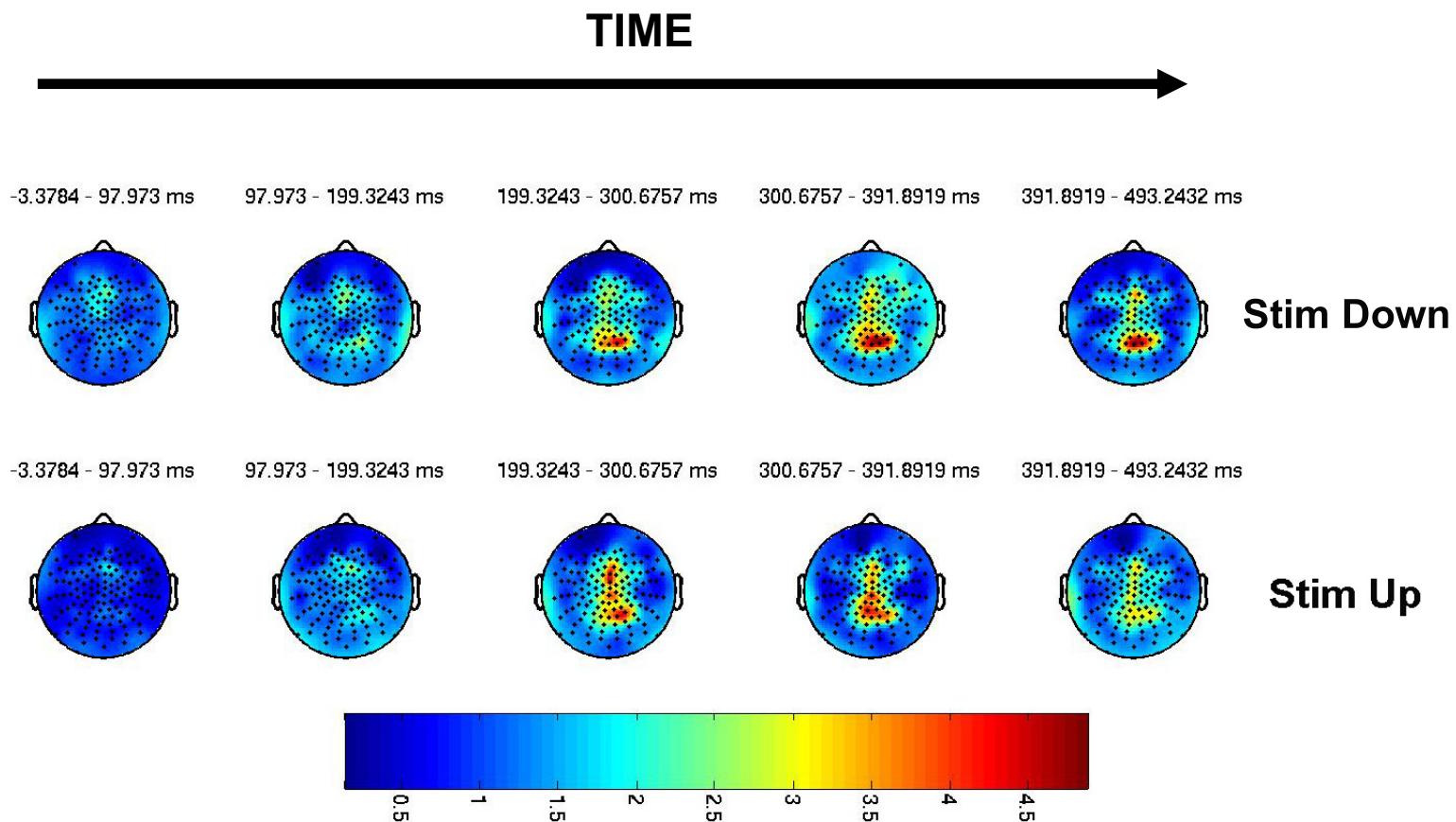
High Gamma Response
80 – 94 Hz



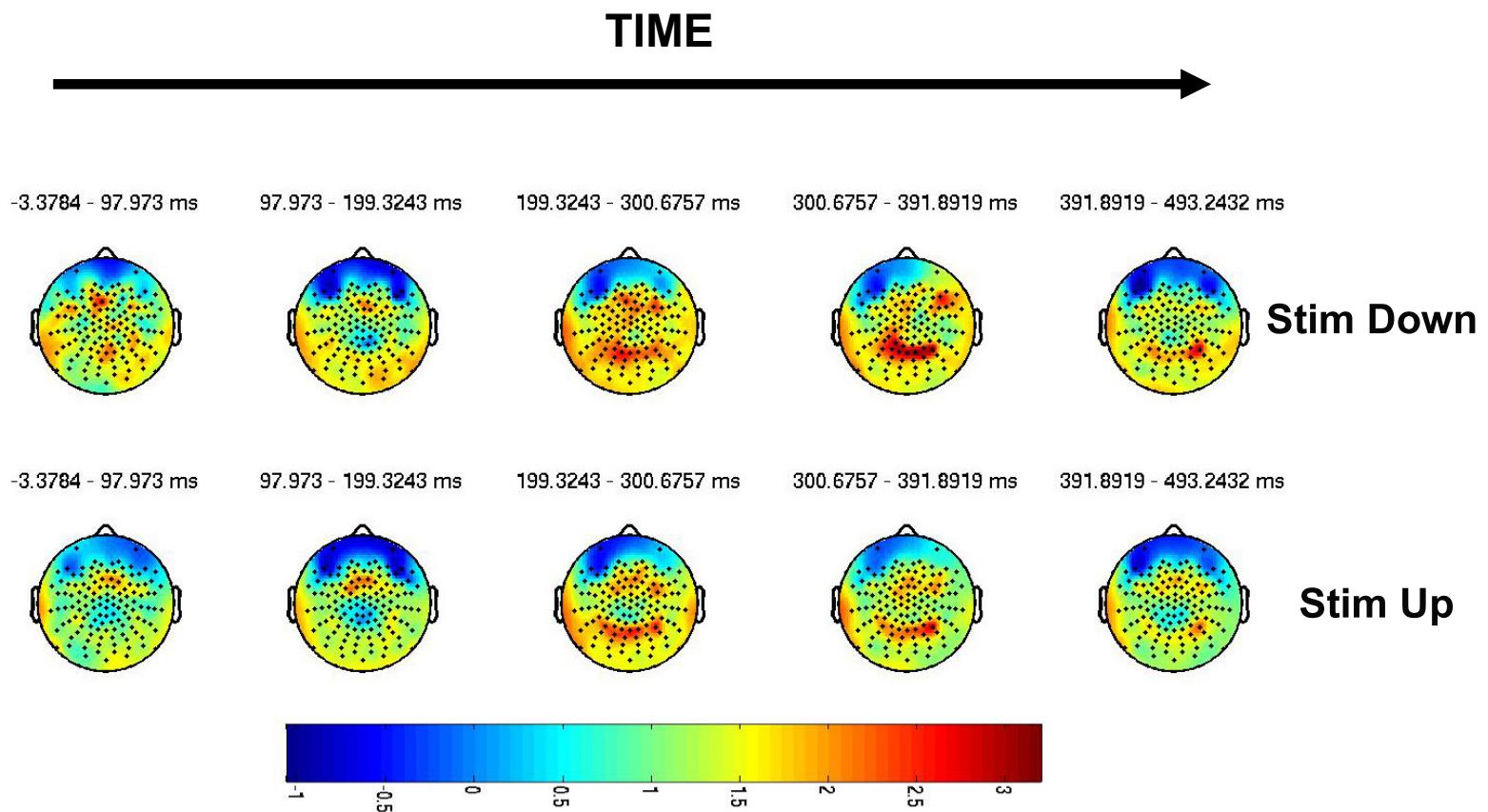
Middle Gamma Response
55 – 70 Hz

VISIBILITY

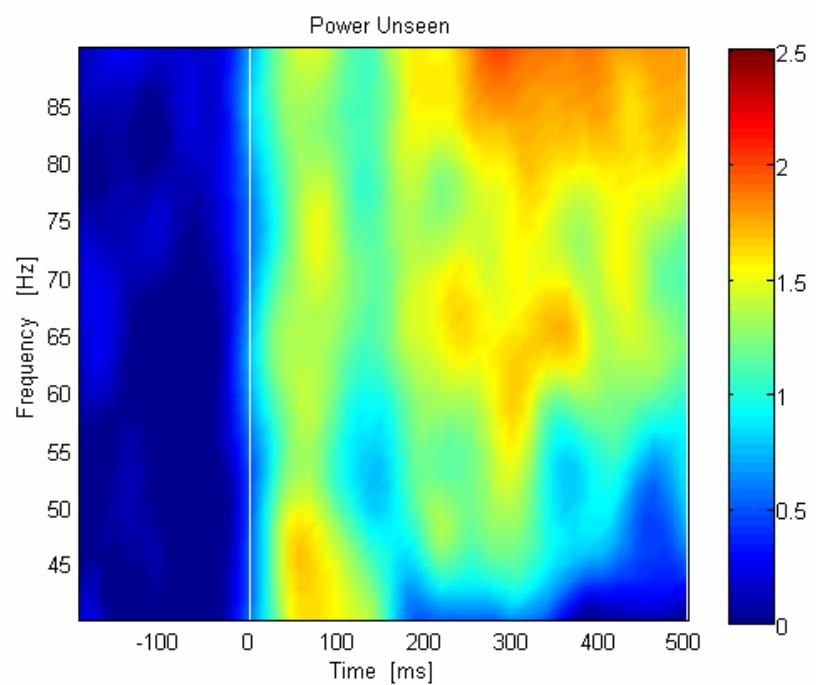
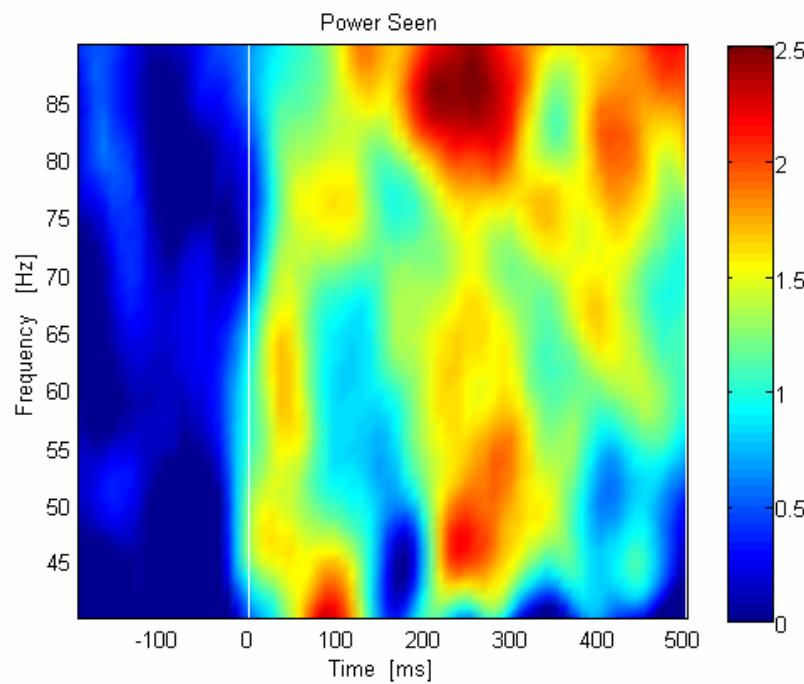
High Gamma response: Top Down



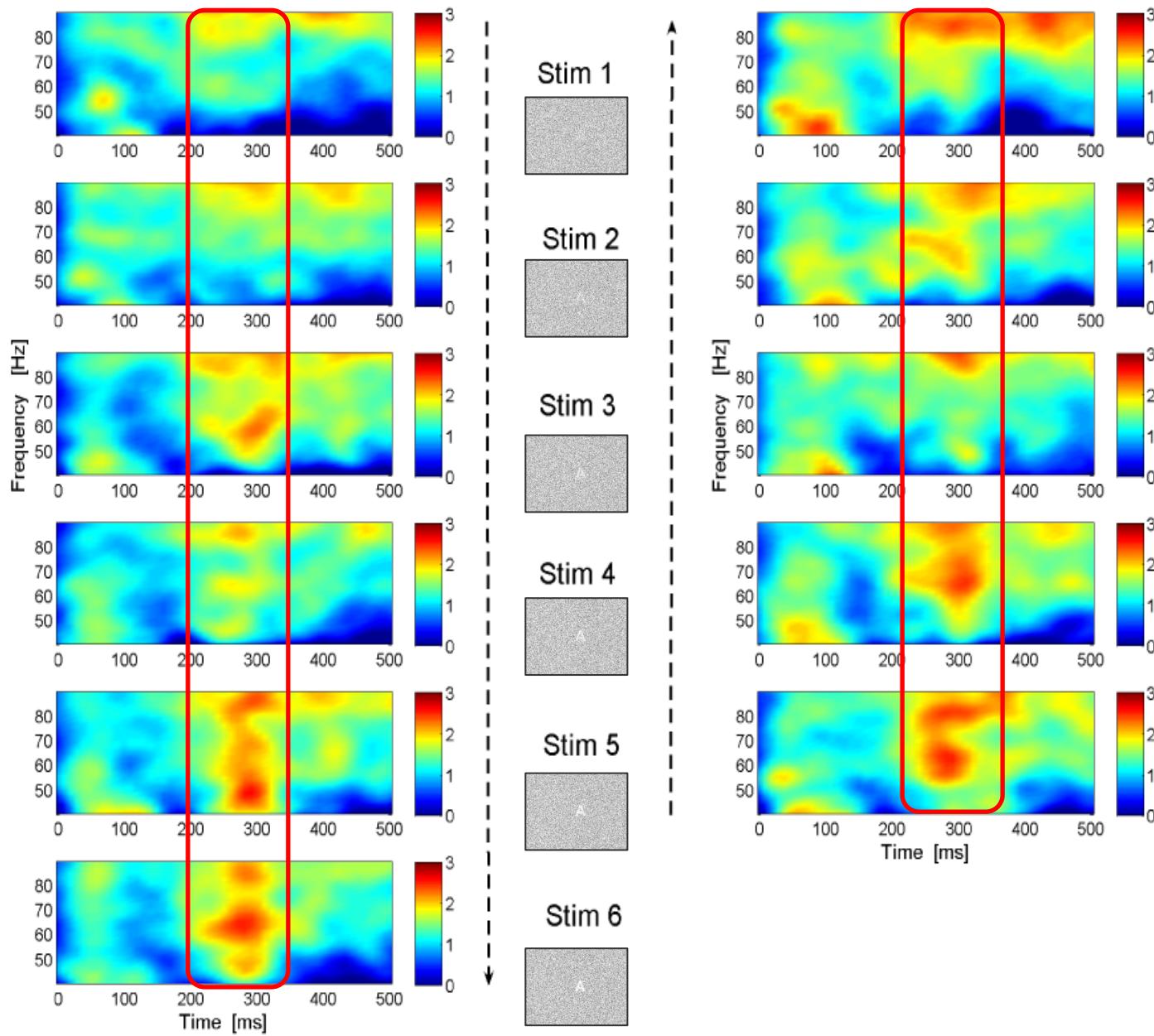
Middle Gamma response: Visibility



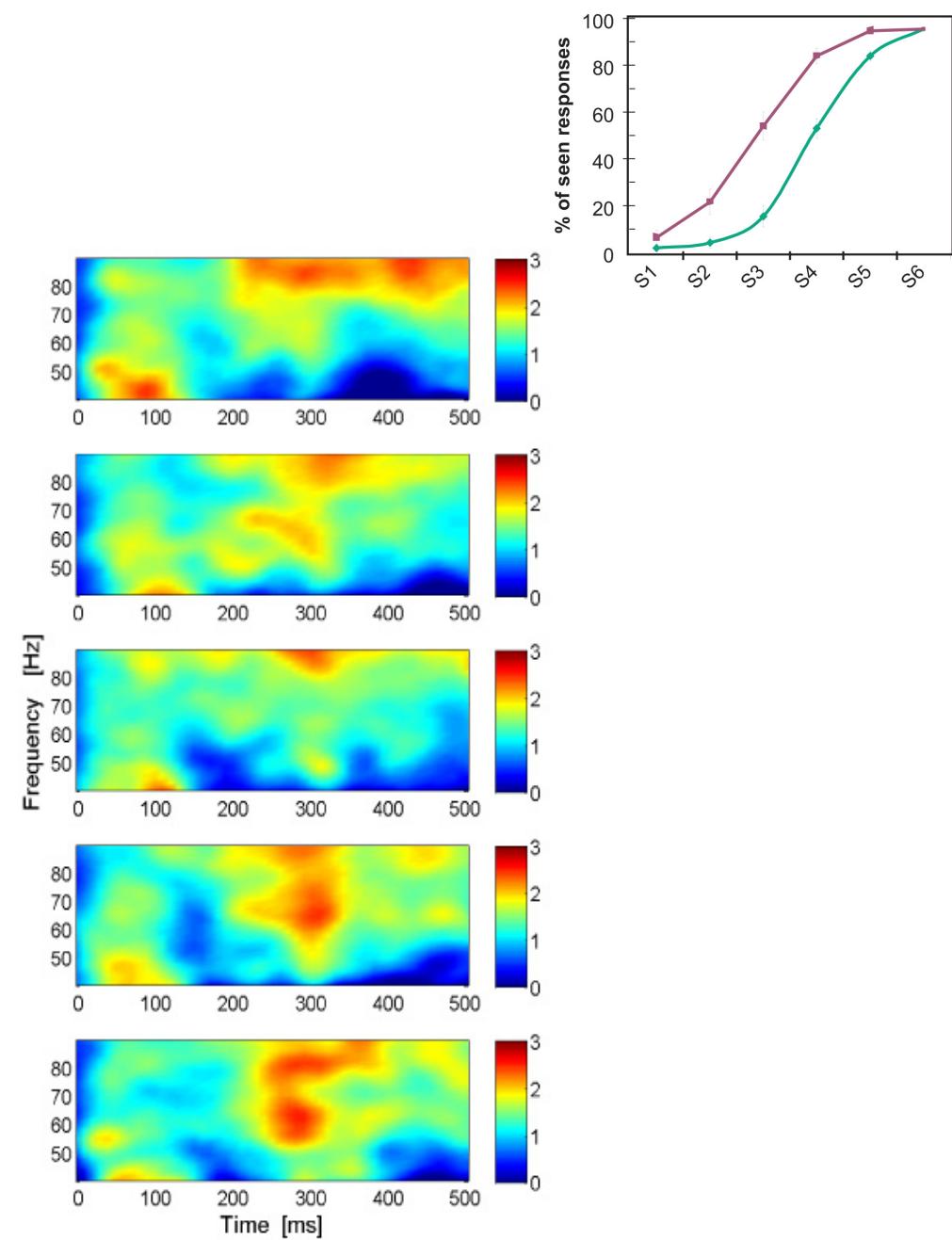
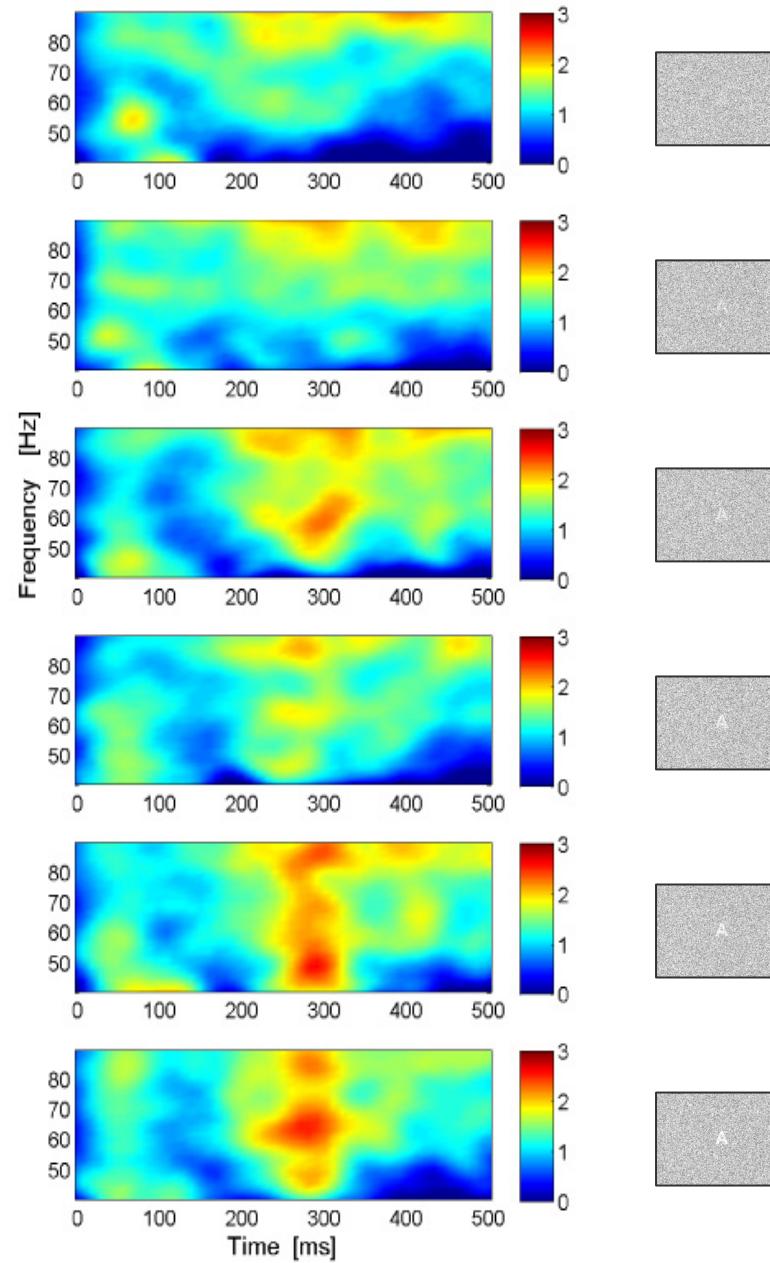
Middle Gamma Response: Visibility



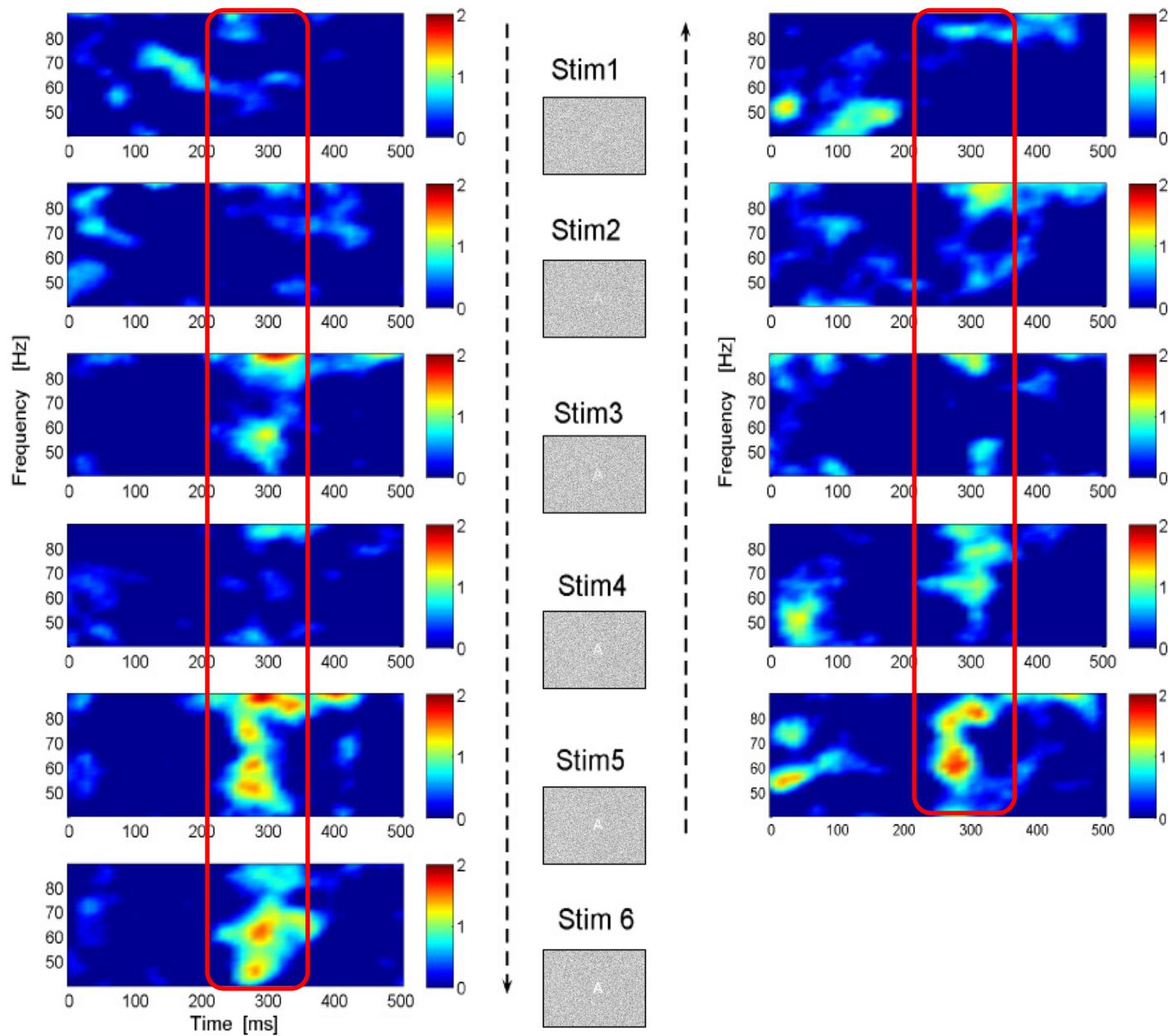
Gamma Power



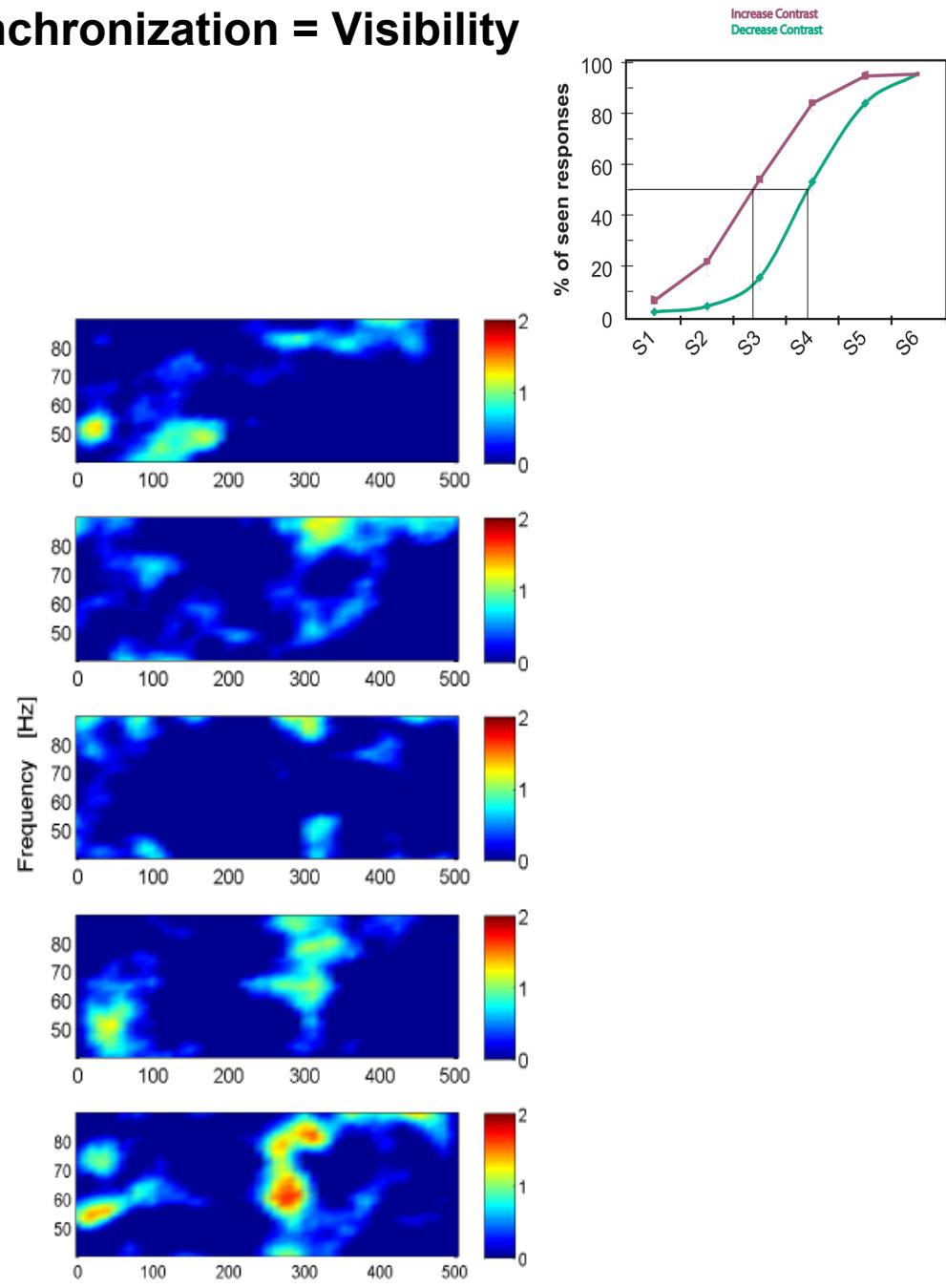
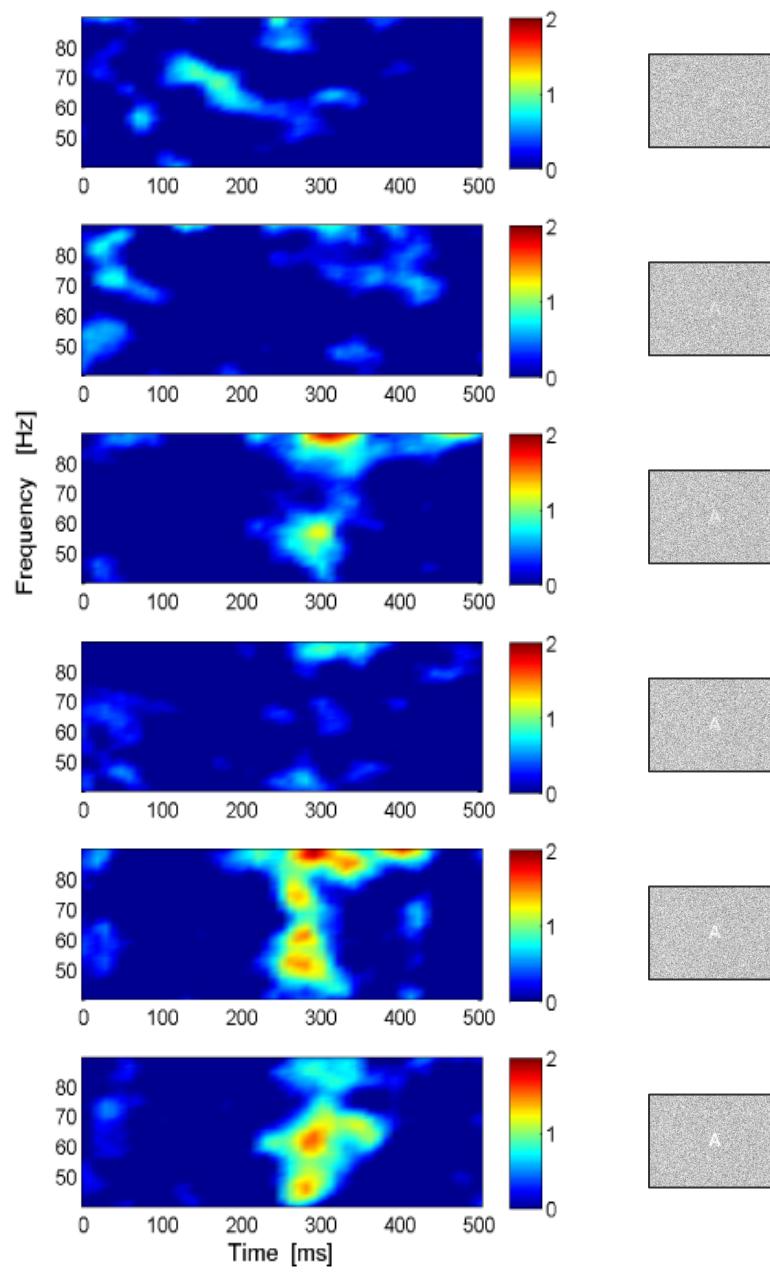
Gamma Power: Shift in the induced gamma response (Hysteresis Effect)



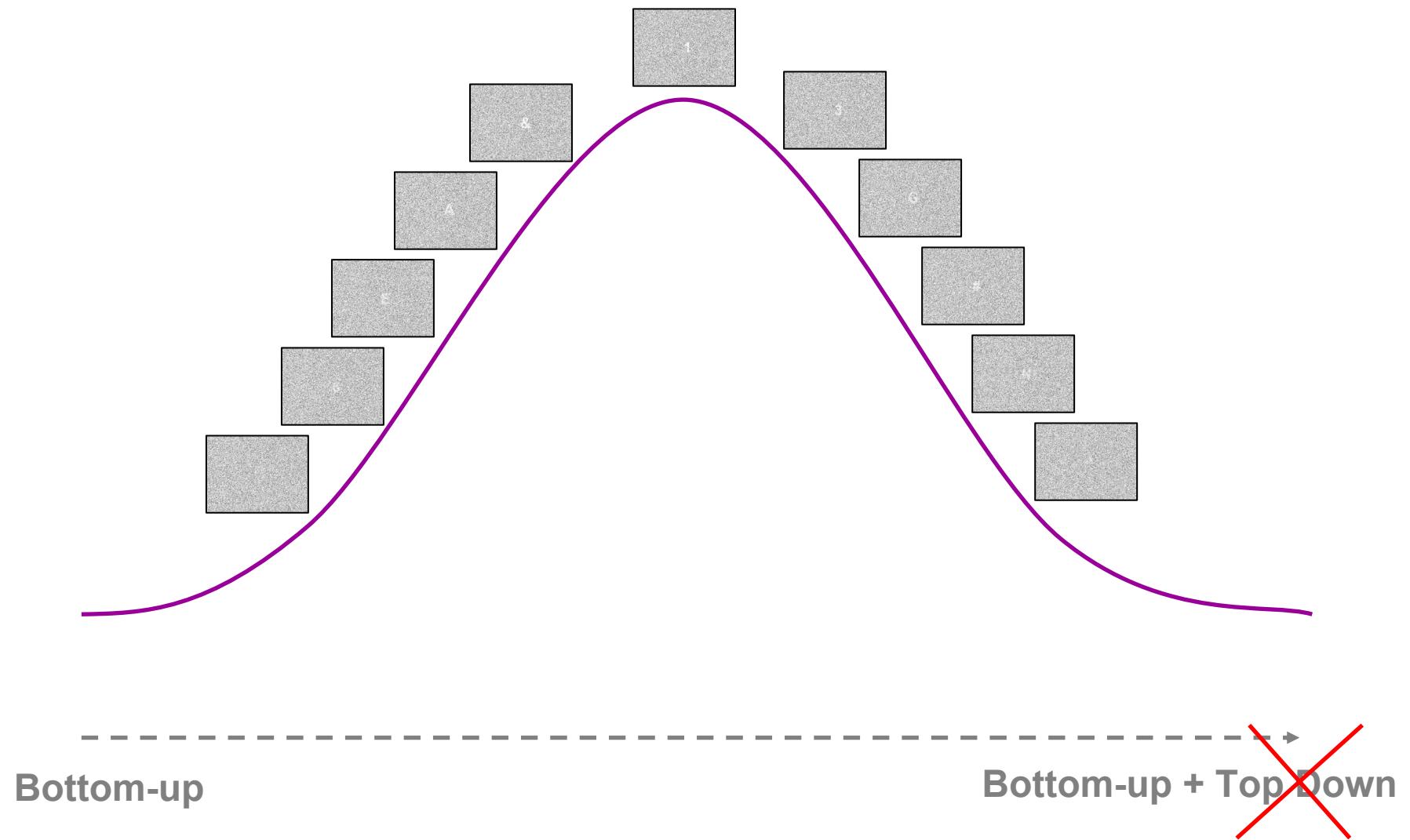
Phase-Locked Synchronization



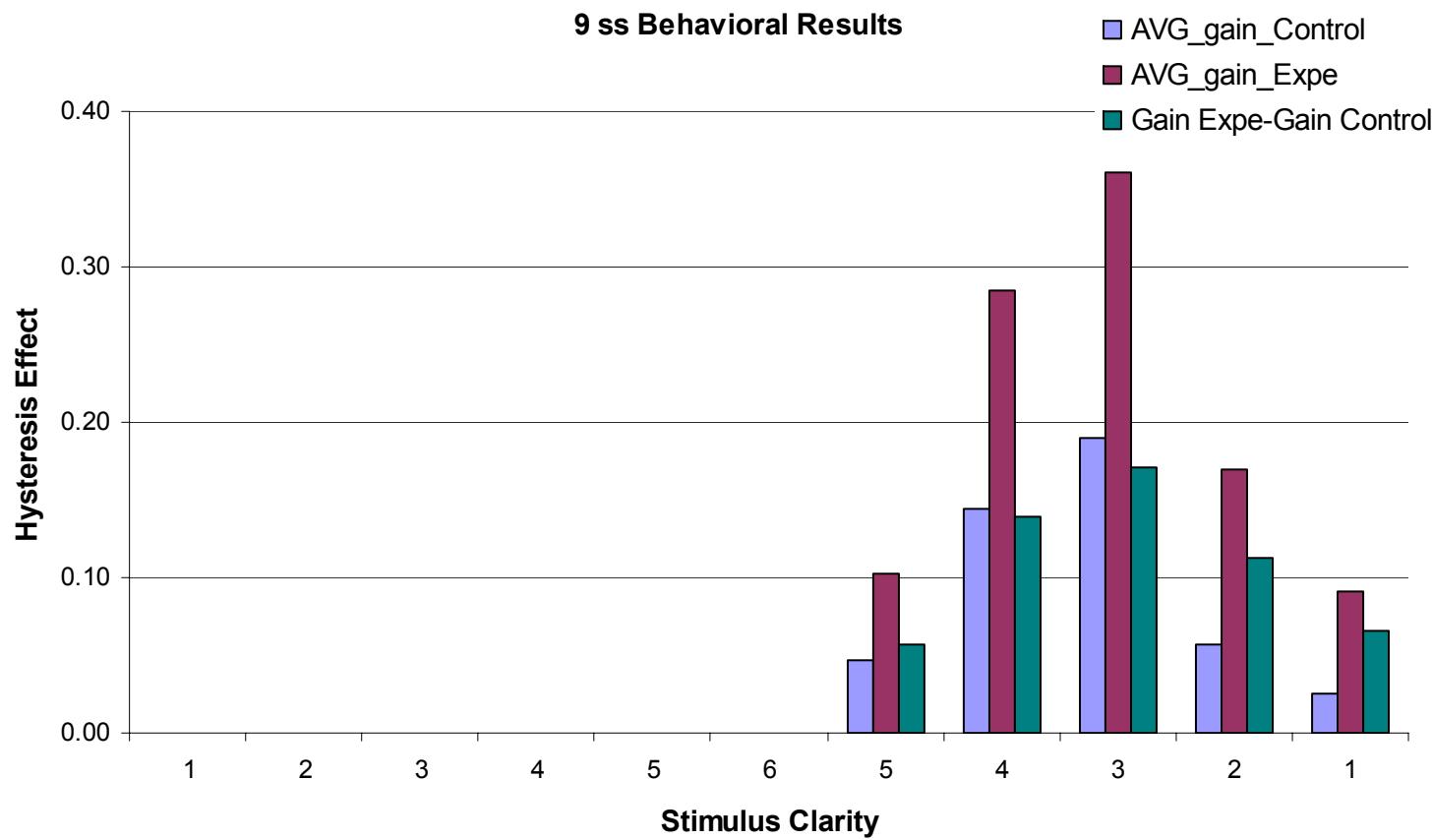
Phase-Locked Synchronization = Visibility



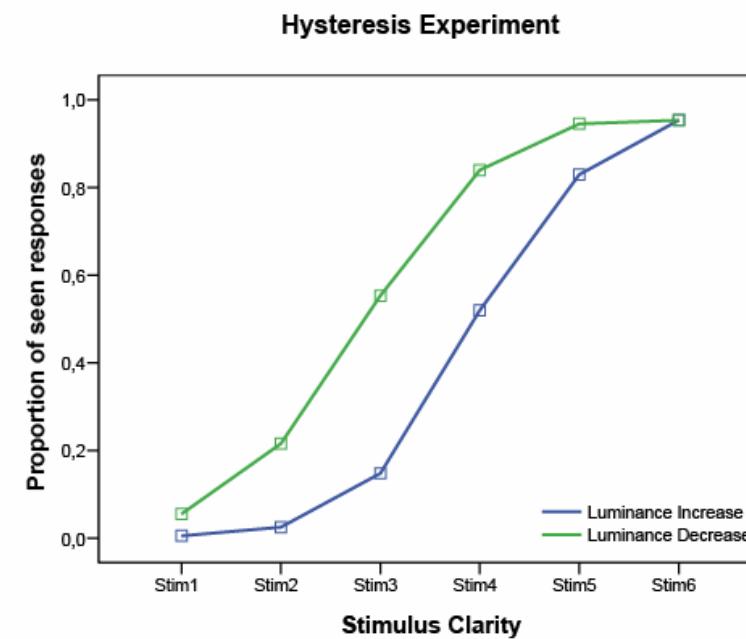
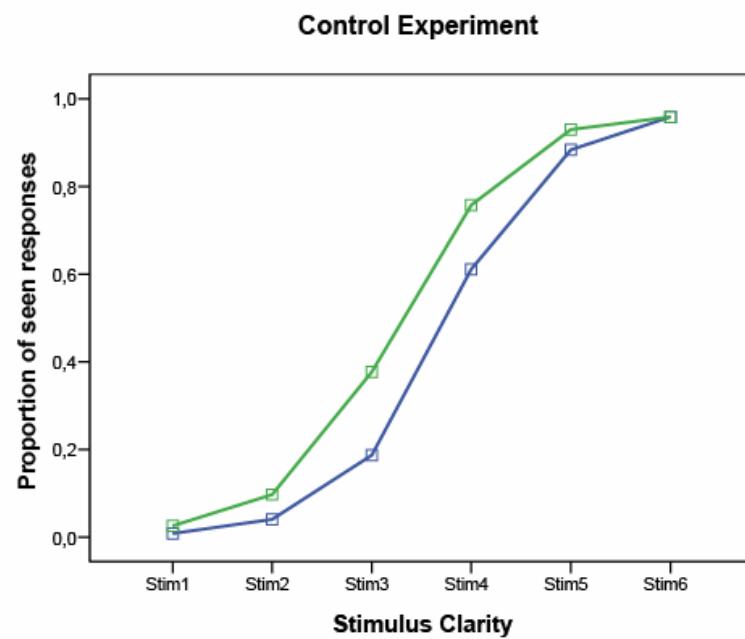
Hysteresis Control Experiment



Hysteresis Control Experiment

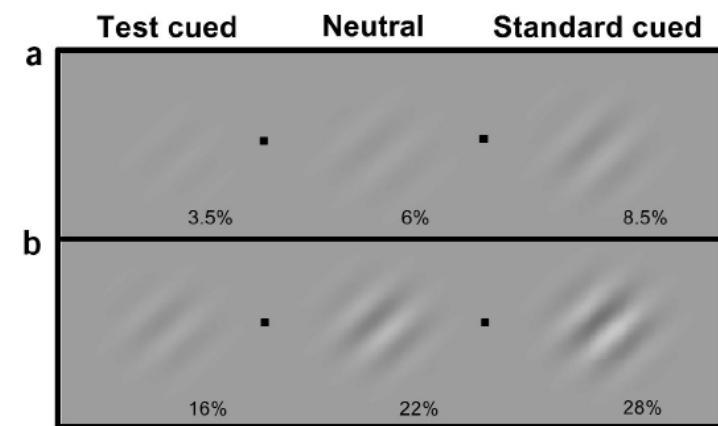
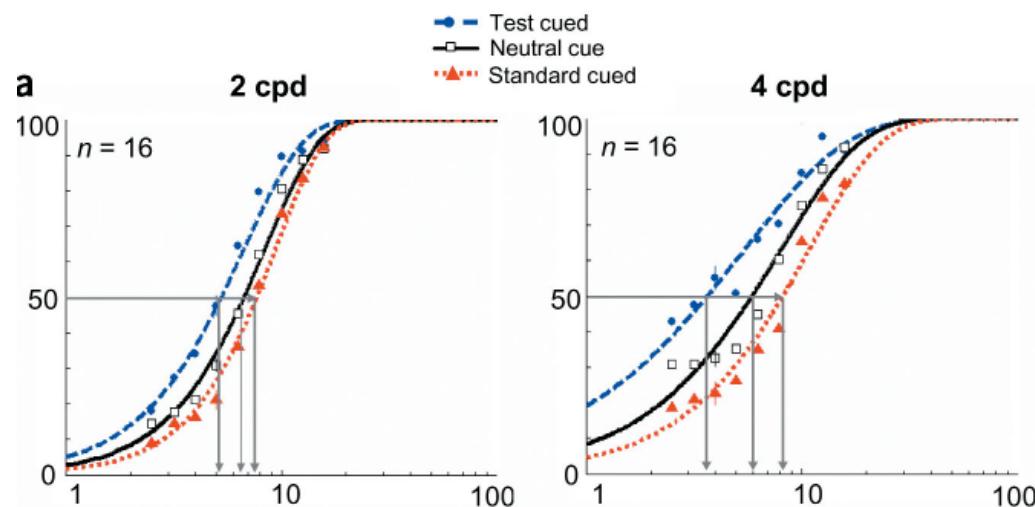


Hysteresis Control Experiment: Behavioral Results



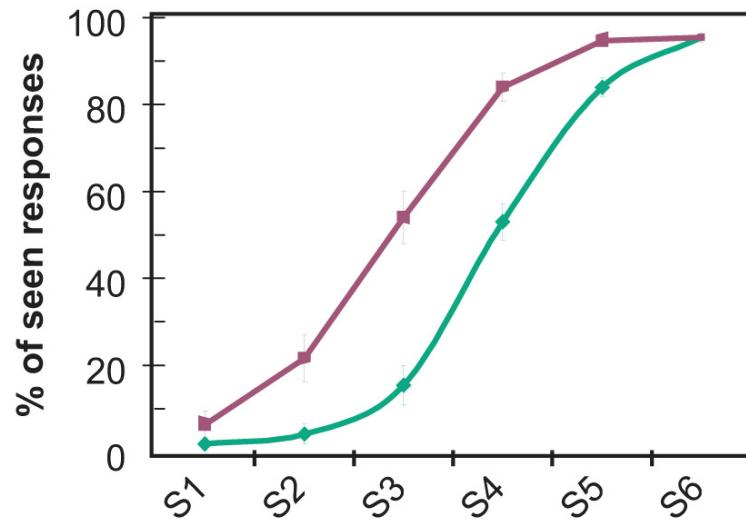
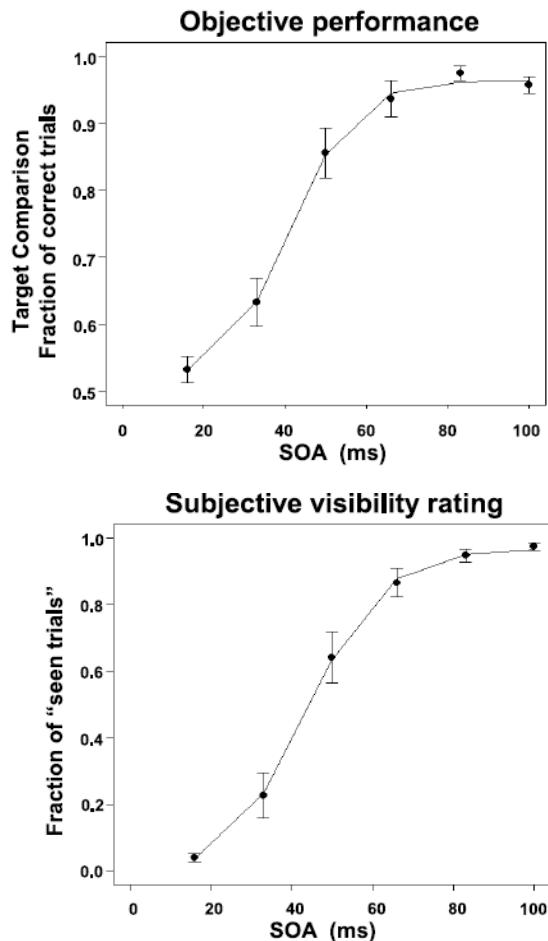
Conclusions (1)

- Top-down alters the saliency of stimuli making them more visible by a factor of 1 stimulus. (In agreement with Marissa Carrasco's studies showing that attention alters experience)



Conclusions (2)

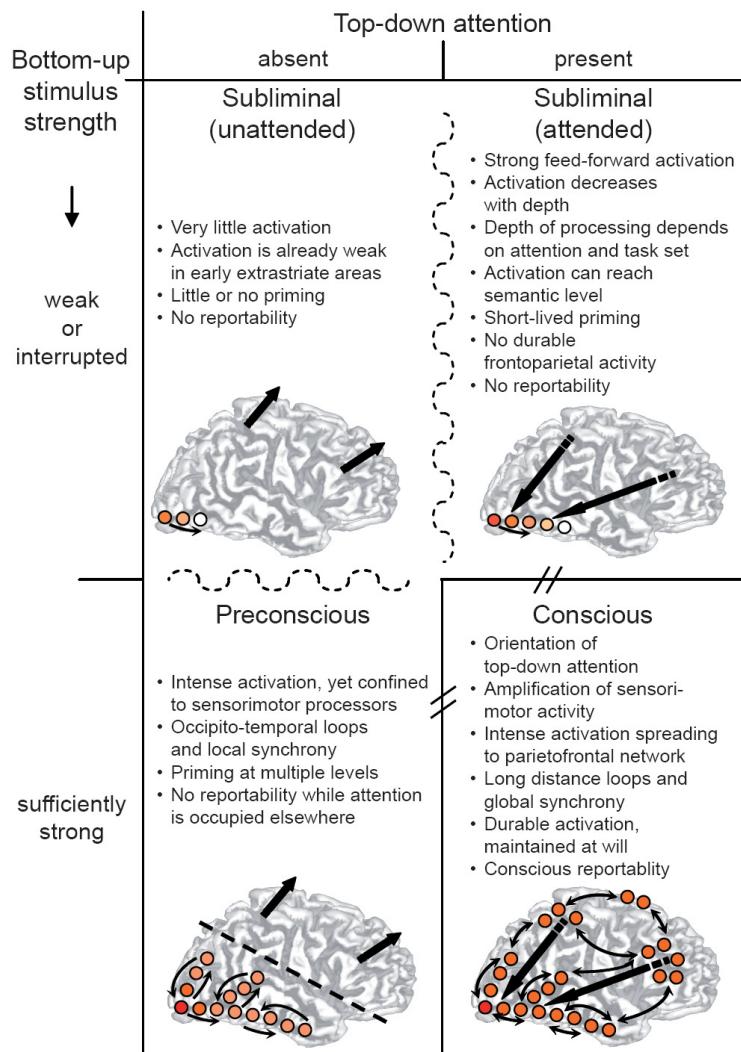
- The curve relating the percentage of seen trials to stimulus contrast is well fitted by a sigmoid → Conscious perception seems to follow a nonlinear (sigmoid) function



Conclusions (3)

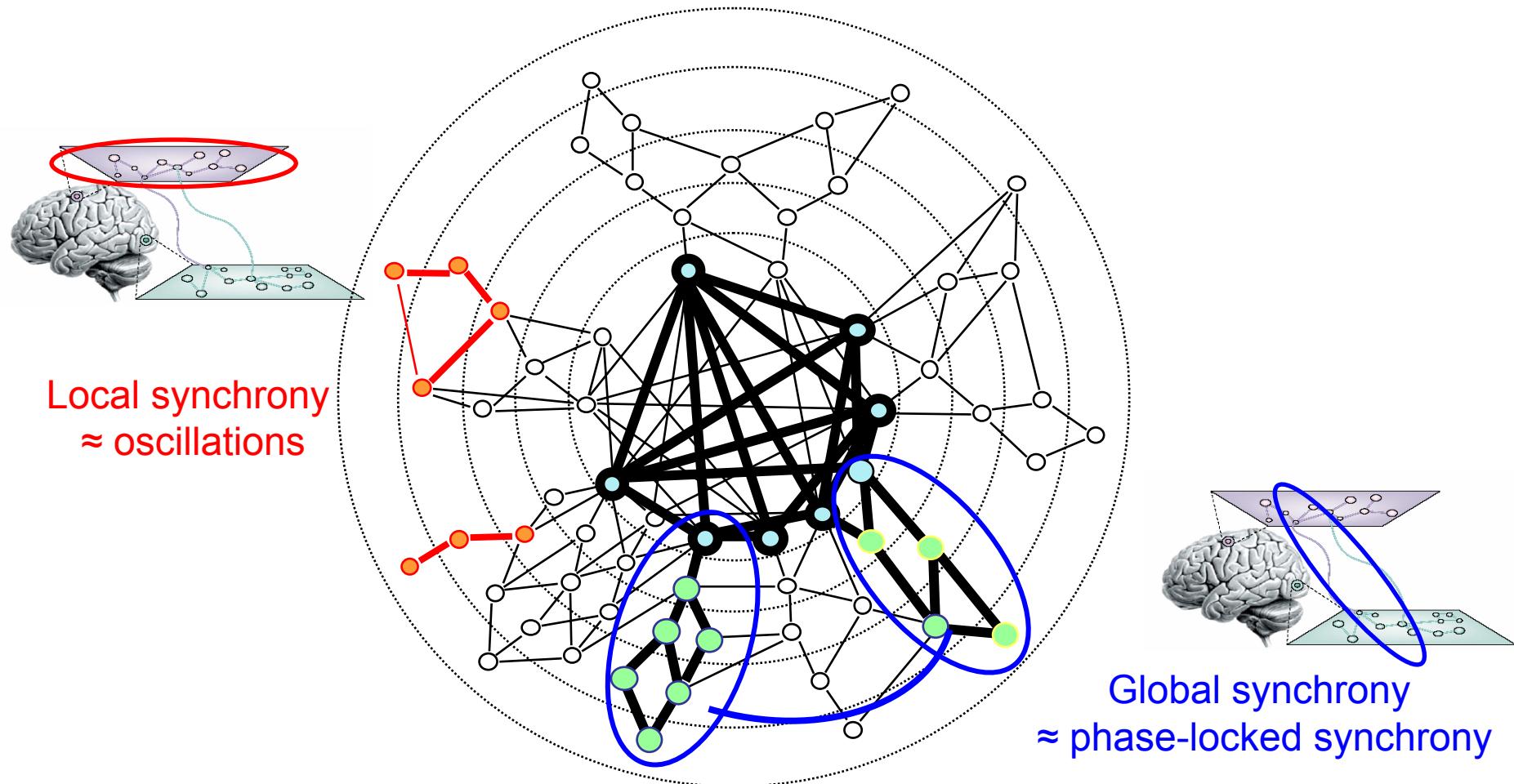
- **ERP:** Amplitude modulated by the contrast and visibility of the stimuli. Amplitude modulation shows an hysteresis effect, indicating that top down affects the sensory processing of those stimuli.
- **Gamma Power:** It follows the hysteresis effect
- **Long-Range Synchrony:** It seems to follow the conscious perception/visibility of the stimulus.

Conclusions (4)



**Top-down representations:
Not only top-down attention can alter consciousness**

Conclusions (5)



Dehaene, Kerszberg & Changeux, PNAS, 1998
inspired by Mesulam, Brain, 1998

Thank you for your attention!

- Thanks to my colleagues:



MPIH, Frankfurt



Neurology Department
Johann Wolfgang
Goethe University

Wolf Singer
Eugenio Rodriguez
Raul Muresan
Caspar M. Schwiedrzik

Notger Müller
Sara Van Leeuwen