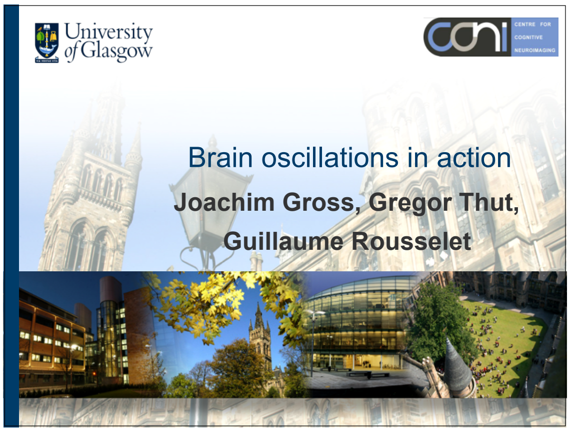
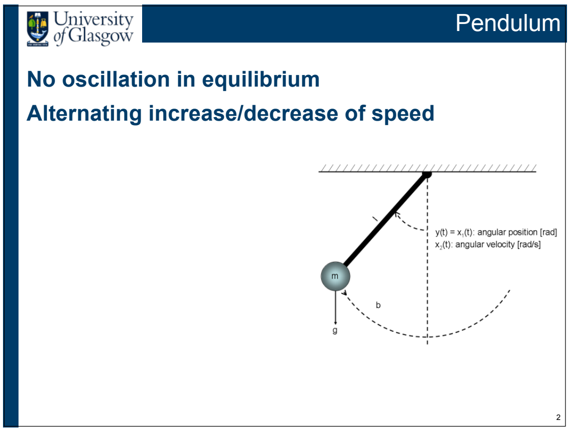


Brain oscillations in action

Joachim Gross, Gregor Thut, Guillaume Rousselet

Outline

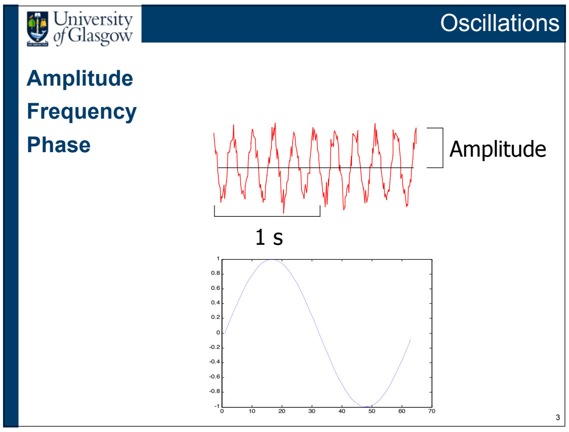
	LECTURE SUMMARY	LEARNING OBJECTIVES
1 to 3	Oscillations: Mechanisms of generation and Analysis	Students will be able to: 1. describe mechanisms by which neuronal elements give rise to oscillatory activity 2. explain how brain activity can be measured by magneto- and electroencephalography (MEG, EEG) 3. describe the main features of oscillations (such as amplitude, phase, frequency), and how they can be anaylzed and interpreted
4 to 6	Oscillations: Relation to evoked activity	Students will be able to: 4. describe the main models relating evoked and induced brain activities 5. explain the implications of these models of oscillatory activity for models of cognition
7 to 10	'Oscillations: Functions and methods of interventions	Students will be able to: 6. describe experiments/paradigms on the role of oscillations in vision, attention, memory and cognition 7. explain how different features of brain oscillations (frequency, phase, amplitude, coherence) are thought to relate to the brain operations underliyng the above processes 8. discuss pitfalls in the interpretation of MEG/EEG-signals due to muscular activity (e.g. gamma and microsaccades) 9. discuss interventional methods to manipulate brain oscillations and possible applications



Pendulum

No oscillation in equilibrium

Alternating increase/decrease of speed

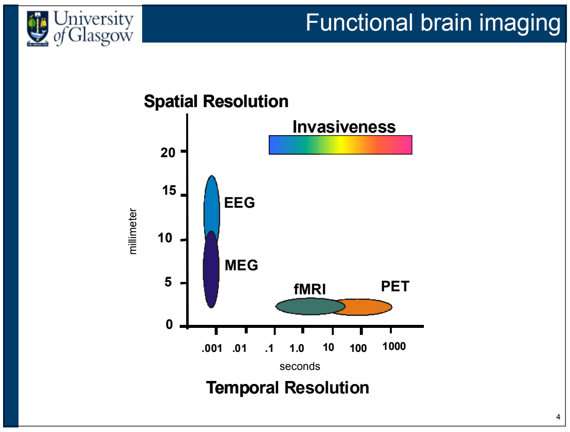


Oscillations

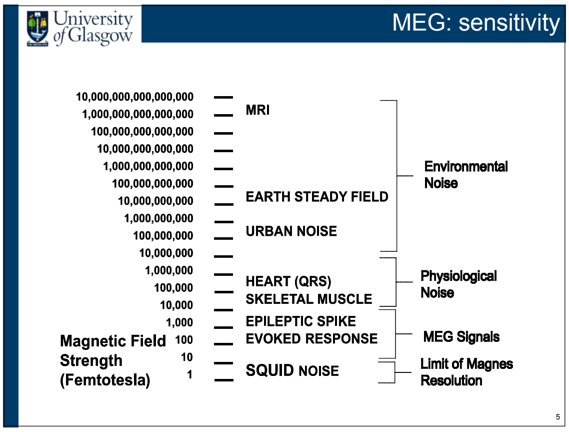
Amplitude

Frequency

Phase



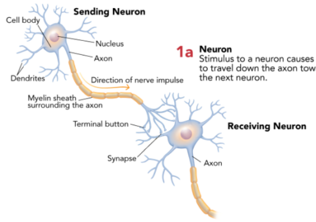
Functional brain imaging



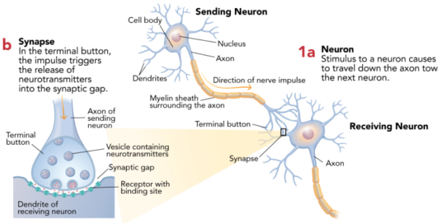
MEG: sensitivity

MEG

What are we measuring?

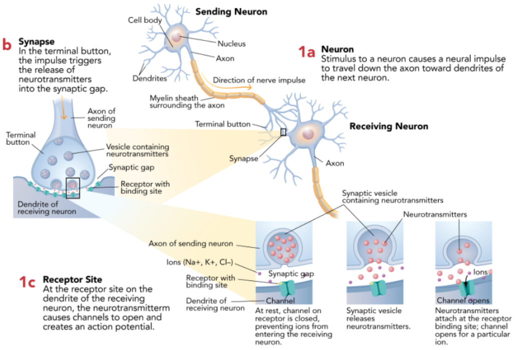


1a Neuron
Stimulus to a neuron causes a neural impulse to travel down the axon toward dendrites of the next neuron.



1b Synapse
In the terminal button, the impulse triggers the release of neurotransmitters into the synaptic gap.

1a Neuron
Stimulus to a neuron causes a neural impulse to travel down the axon toward dendrites of the next neuron.



1b Synapse
In the terminal button, the impulse triggers the release of neurotransmitters into the synaptic gap.

1a Neuron
Stimulus to a neuron causes a neural impulse to travel down the axon toward dendrites of the next neuron.

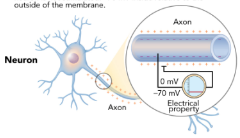
1c Receptor Site
At the receptor site on the dendrite of the receiving neuron, the neurotransmitterm causes channels to open and creates an action potential.

At rest, channel on receptor is closed, preventing ions from entering the receiving neuron.

Synaptic vesicle releases neurotransmitters.

Neurotransmitters attach at the receptor binding site; channel opens for a particular ion.

2a Resting Potential
The electrical potential across the membrane when the neuron is not stimulated. –70 mV inside relative to the outside of the membrane.



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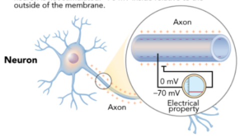
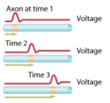
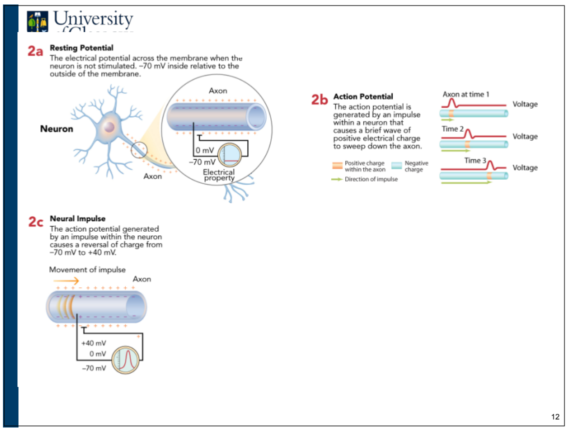


2b Action Potential
The action potential is generated by an impulse within a neuron that causes a brief wave of positive electrical charge to sweep down the axon.



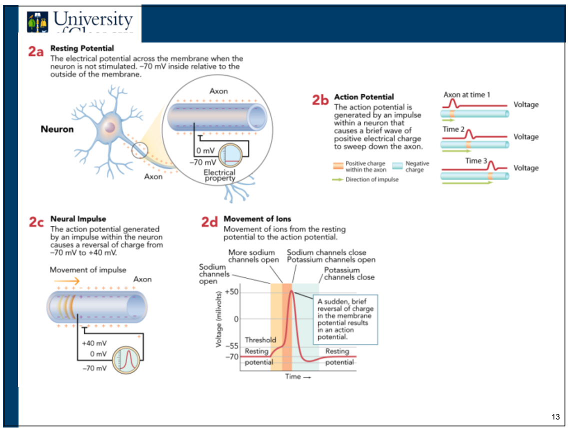
🟧 Positive charge within the axon
🟦 Negative charge
→ Direction of impulse



2a Resting Potential
The electrical potential across the membrane when the neuron is not stimulated. –70 mV inside relative to the outside of the membrane.

2b Action Potential
The action potential is generated by an impulse within a neuron that causes a brief wave of positive electrical charge to sweep down the axon.

2c Neural Impulse
The action potential generated by an impulse within the neuron causes a reversal of charge from –70 mV to +40 mV.



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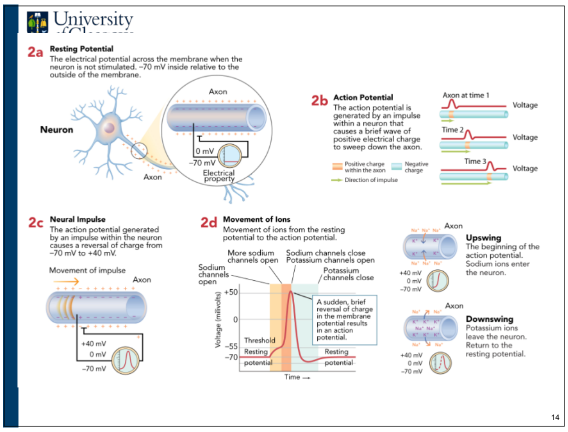
The action potential generated by an impulse within the neuron causes a reversal of charge from –70 mV to +40 mV.

2d Movement of Ions
Movement of ions from the resting potential to the action potential.

A sudden, brief reversal of charge in the membrane potential results in an action potential.



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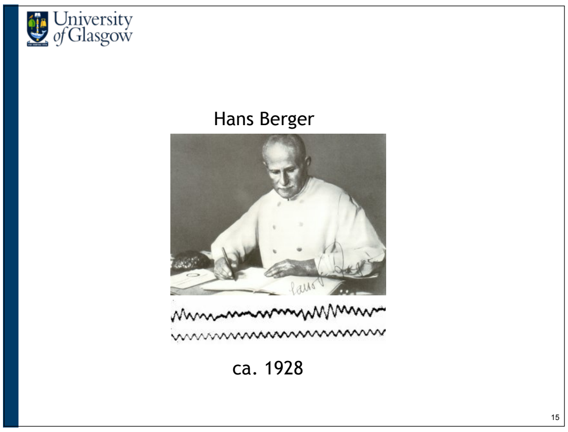
Movement of ions from the resting potential to the action potential.

A sudden, brief reversal of charge in the membrane potential results in an action potential.

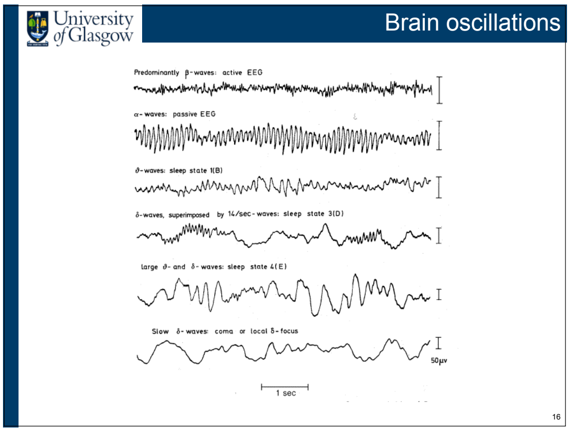
Upswing
The beginning of the action potential. Sodium ions enter the neuron.

Downswing
Potassium ions leave the neuron. Return to the resting potential.

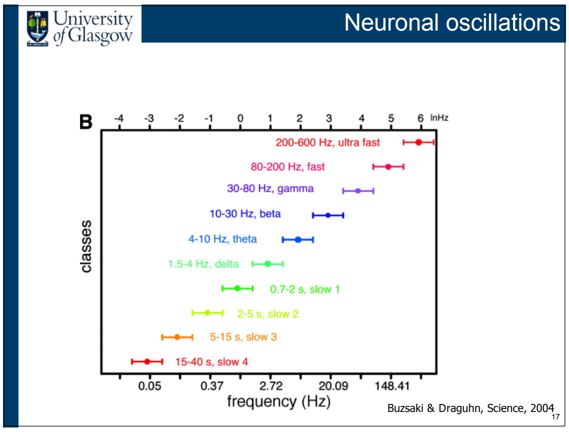


Hans Berger

ca. 1928



Brain oscillations



Neuronal oscillations

Buzsaki & Draguhn, Science, 2004

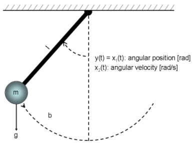
Mechanisms of generation

We need two opposing forces/effects

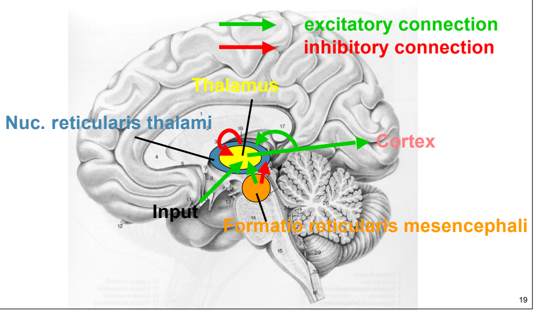
In the brain these are: excitation, inhibition

3 mechanisms:

1. **Pacemaker cells**
2. **Local generator**
3. **Thalamo-cortical generator**

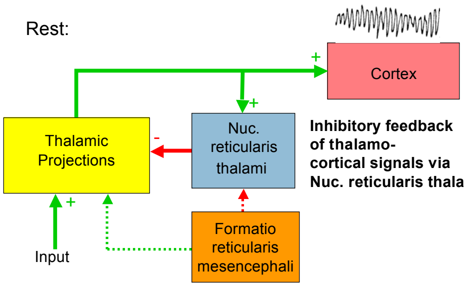


Thalamo-cortical system



Alpha-oscillations

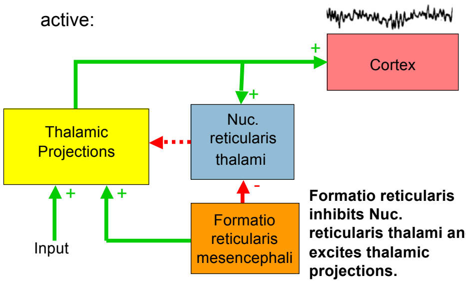
Rest:



Inhibitory feedback of thalamo-cortical signals via Nuc. reticularis thalami.

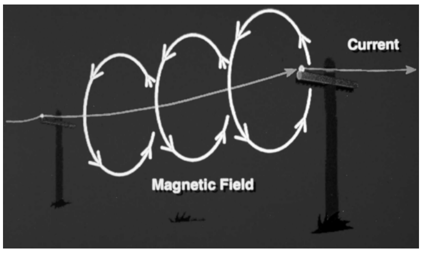
Beta-oscillations

active:



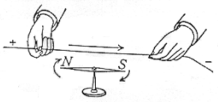
Formatio reticularis inhibits Nuc. reticularis thalami and excites thalamic projections.

Magnetic fields



Magnetic fields

H.C. Oersted, 1820:



Deflection of compass needle by electric current

MEG

How are we measuring?

SQUIDS

Shielded room

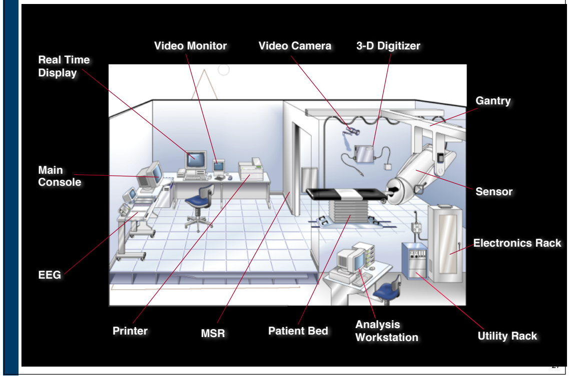
(noise cancellation)

Magnetically shielded room (MSR)

Magnetoencephalography

Direct measurement of neural activity with high temporal and good spatial resolution

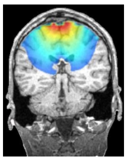
MEG system



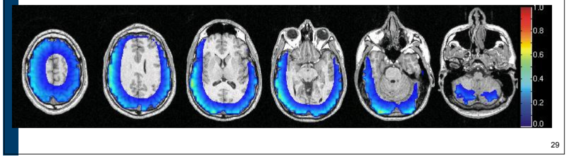
Magnetoencephalography (MEG)

Sensitivity of MEG system

Single sensor



Sensitivity of whole-head system



MEG

Analysis

Preprocessing

Source localization

Analysis in time and frequency domain

Preprocessing

Filtering

Artifact rejection/correction

External: 50Hz line noise, magnetic noise, Jumps

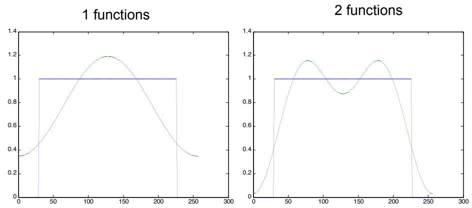
Internal: Eye, heart, muscle, movements

Decimation

Fourier transform – the idea

fitting a function with sinusoids

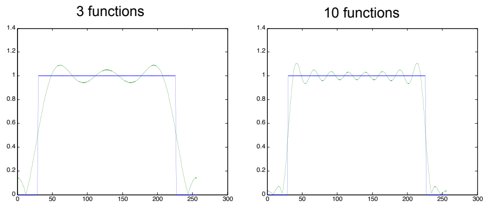
transformation of time series to frequency domain



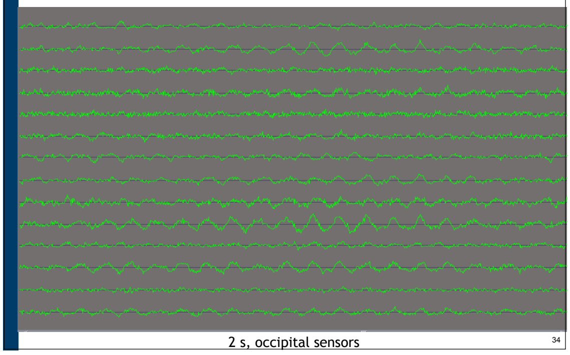
Fourier transform – the idea

fitting a function with sinusoids

transformation of time series to frequency domain

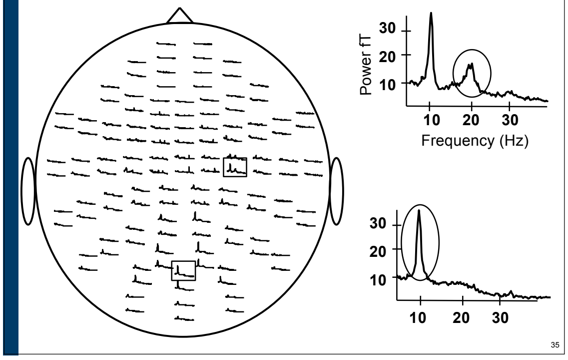


How does it look?

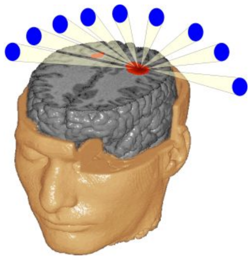


2 s, occipital sensors

Spectral analysis of resting activity



From sensors to brain areas



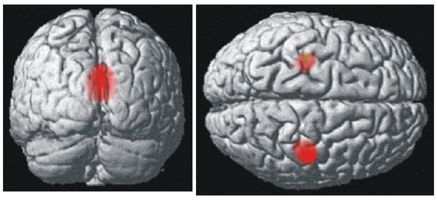
- Mapping signals into the brain

- computation of power in the entire brain

PNAS, 2001

Ongoing oscillations

Localisation of 10 Hz - and 20 Hz - oscillations



10 Hz 20 Hz

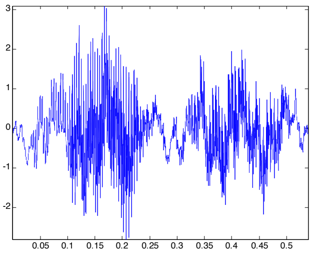
Break

Time-frequency analysis

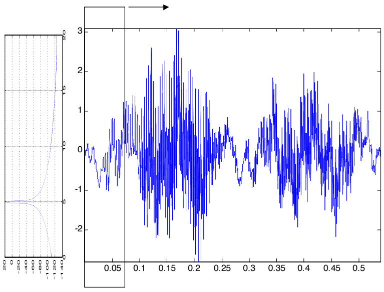
Why TFR?

FFT assumes stationarity!

no time information



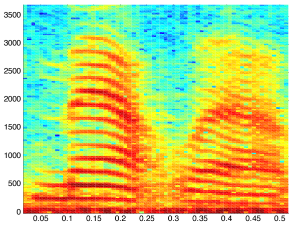
TFR with FFT



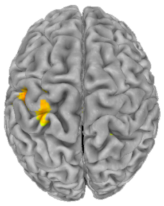
Short-time FT

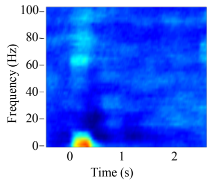
S = spectrogram(x,window,noverlap,nfft,fs);

spectrogram(mtlb,hanning(256),200,256,Fs);



Time-Frequency analysis

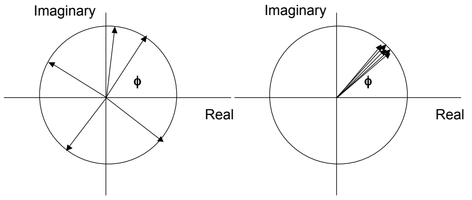




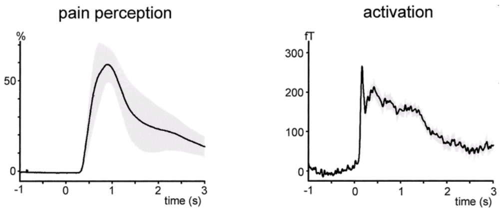
Phase analysis

aim: detect phase-locking (preferred, non-random phase)

for example: phae locking to stimulus

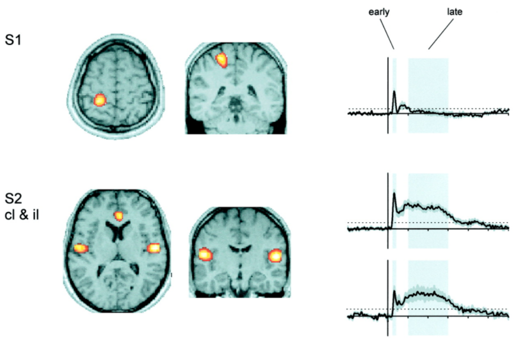


Pain perception

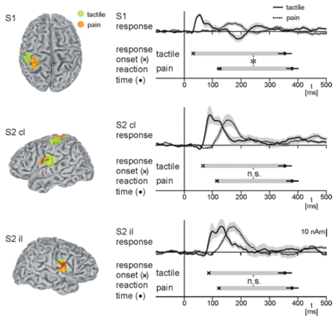


PNAS 2002

Pain processing



Evoked components



Next Week

Short presentation of papers:

- **Ploner, Gross, et al., ‘Pain suppresses spontaneous brain rhythms’. Cerebral Cortex, 2005**
- **Kilner, Salenius, et al. “Task-Dependent Modulations of Cortical Oscillatory Activity..”, Neuroimage, 2002**
- **Pfurtscheller, Zalaudek, et al. “Event-related beta synchronization …”, Electroencephalography and Clinical Neurophysiology, 1998**

Lectures 8-10 (Gregor Thut)

	Oscillations:	Covers e.g.:	Papers:
Lecture 8	New methods in research on oscillations beyond EEG/MEG – Interventional techniques	New findings on the alpha-frequency band (interfacing visual input regulation and memory)	• Thut G, Miniussi C. New insights into rhythmic brain activity from **TMS-EEG** studies. **Trends Cogn Sci** 2009 13:182-9. • Sauseng P et al. Brain oscillatory substrates of visual short-term memory capacity. **Curr Biol 2009** 19(21):1846-52.
Lecture 9	• Low-frequency alpha (theta) oscillations • High-frequency gamma oscillations	• Role in low-level vision (input control) • Role in high-level vision (feature binding, and others)	-Schroeder CE, Lakatos P. Low-frequency neuronal oscillations as instruments of sensory selection. **Trends Neurosci 2009** 32(1):9-18. -Uhlhaas PJ, et al. Neural synchrony in cortical networks: history, concept and current status. **Front Integr Neurosci 2009** 3:17.
Lecture 10	Pitfalls in interpreting oscillatory activity	The emg contamination	• Yuval-Greenberg et al. Transient induced gamma-band response in EEG as a manifestation of miniature saccades. **Neuron. 2008** 58(3):429-41.. • Melloni L et al. (Micro)Saccades, corollary activity and cortical oscillations. Trends Cogn Sci. 2009 13(6):239-45.

With a focus on predictive oscillations (lectures 8-9)