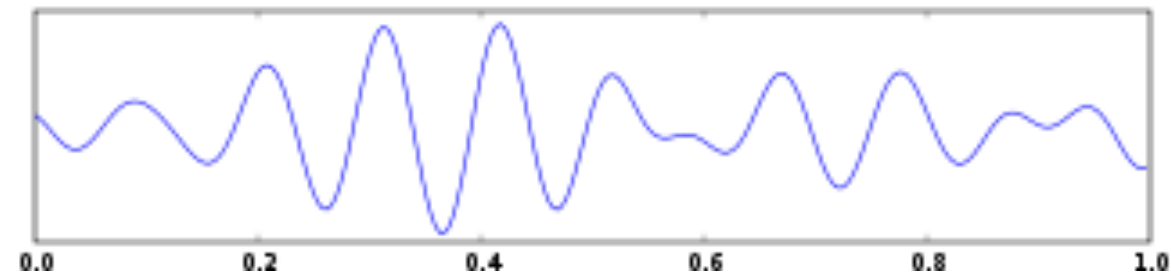




**Donders Institute**  
for Brain, Cognition and Behaviour

**Linsey Roijendijk, October 25th 2011**

## **Attention based BCIs using alpha band oscillations**



**Radboud University Nijmegen**





## Teaching goals

- Familiarizing you with **alpha** based **BCI's** regulated by **attention**:
  - What is “attention”?
  - Why are attention based paradigms used for BCIs?
  - What is the alpha-rhythm and how can it be modulated?
  - What are the different types of alpha based BCIs  
(alertness, spatial as well as feature attention) and how do they work?  
Which brain signatures do they use?
  - What are the open issues?





## What is attention?

- “**Attention** acts as a means of focusing limited mental resources on the information and cognitive processes that are most salient at a given moment” (Sternberg, 1999)
- Attention **selects** what is being processed and what will be ignored in the brain
  - Example: this lecture!
- Attention is necessary because of **limited capacity** of the brain
- When an object or process is attended, processing is more efficient
- **Vigilance/alertness** is about the state of the brain (and not a process)





## Exogenous versus endogenous attention

- **Exogenous attention**
  - Attention captured by salient stimuli in the environment (involuntary)
  - For example:
    - Hearing a sound in a quiet room
    - Cocktail party effect
- **Endogenous attention**
  - Voluntary direction of your attention
  - For example:
    - You listening to me or paying attention to something else from your sensory inputs
  - Prepare attention for an upcoming stimulus





## Why use it for BCI?

- Why use it for BCI
  - Orienting your attention is a natural process
  - **Covert attention:**  
You don't need to use your muscles for it (good for patients!)
  - Processing in the brain is enhanced during attention => Change in brain activity
- Ideal situation:  
  
Detection of  
**where** someone's attention is (spatial)  
and **what** he/she is attending to (feature)





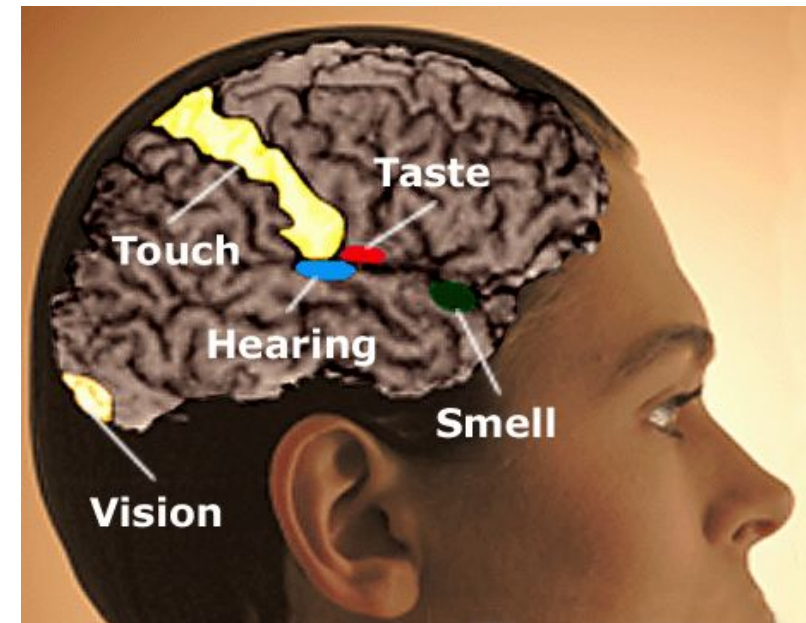
## Example of alpha attention based BCI

You are  
on a bike



## Types of attention

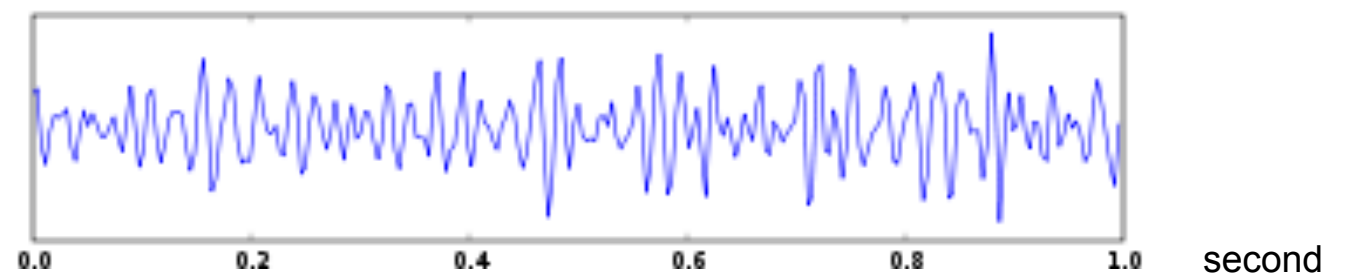
- Sensory attention
  - Visual
  - Tactile
  - Auditory
  - Olfactory (smell)
  - Gustatory (taste)
- Feature attention
  - Spatial (visual/tactile/auditory)
  - Color/shape/motion (visual)
  - Texture (tactile)
  - Pitch, rhythm, etc (auditory)
- BCI: can we distinguish different brain patterns within/over these types of attention?





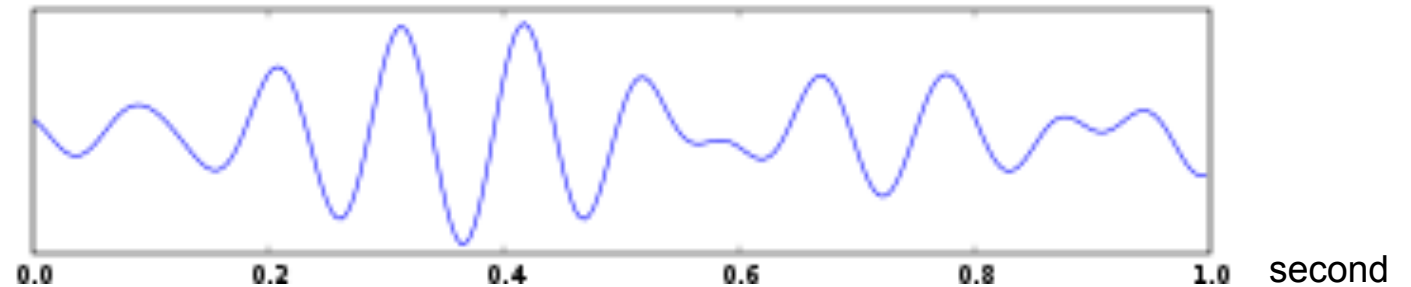
## Stimulus driven attention brain signals

- Event related potentials:
  - P300
  - Attention-directing anterior negativity (ADAN)
  - Contingent Negative Variation (CNV)
- Oscillations:
  - Gamma oscillations (30-150 Hz) increase in brain regions involved in cognitive processing



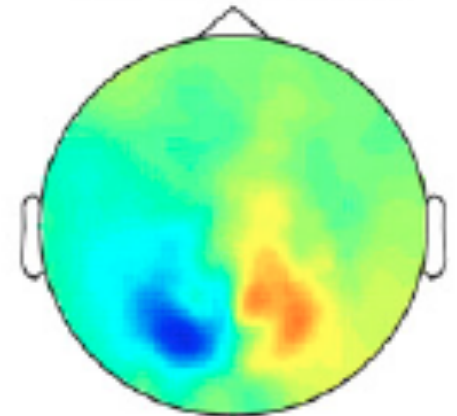


## Alpha (8-13 Hz)



- First reported in 1920s by Hans Berger
- Far strongest measurable electrophysiological signal in the human brain (1/f effect and good for BCI => Strong signal-to-noise)
- Strongest during rest, also called the 'idling rhythm' (!remember the eyes closed from the demo session)  
=> **Idling hypothesis: few mental operations occurring**
- When you're less alert you're overall alpha level will increase!
- Occurring in the occipital and parietal cortex

## Specific alpha patterns

- 2002 on: Evidence that alpha activity can actually increase with cognitive load and can be modulated by doing certain tasks!
  - For example: visual covert attention to a certain hemifield gives a lateralized response (just as with imagined movement but different region)
  - **Inhibition hypothesis**  
(Klimesch et al. (2006), Jensen and Mazaheri et al.(2010)):  
Alpha activity reflects inhibition of regions not involved in a given task, which serves to allocate/gate resources to areas actually involved!
- A topographic map of the human head showing alpha band activity. The map is circular with a color scale from blue (low activity) to red (high activity). A prominent red area is visible in the left hemisphere (viewer's right), indicating high alpha activity, while the right hemisphere (viewer's left) shows lower activity in blue and green.
- BCI: Inhibition of a certain part of the brain can be distinguished from inhibition in other parts!



## Covert attention BCIs

- New direction for BCI!
- First article on visual covert attention BCI published in september 2005 (Kelly et al.)
- Until now there are (I think) less than 20 studies on alpha related covert attention BCIs!  
(There are many fundamental neuroscience papers)
- **Required reading:**  
O. Jensen, A. Bahramisharig, R. Oostenveld, S. Klanke, A. Hadjipapas, Y.O. Okazaki, M.A.J. van Gerven, *Using brain-computer interfaces and brain-state dependent stimulation as tools in cognitive neuroscience*, Frontiers in Psychology, May 2011



## Passive BCI: Alertness/Relaxation

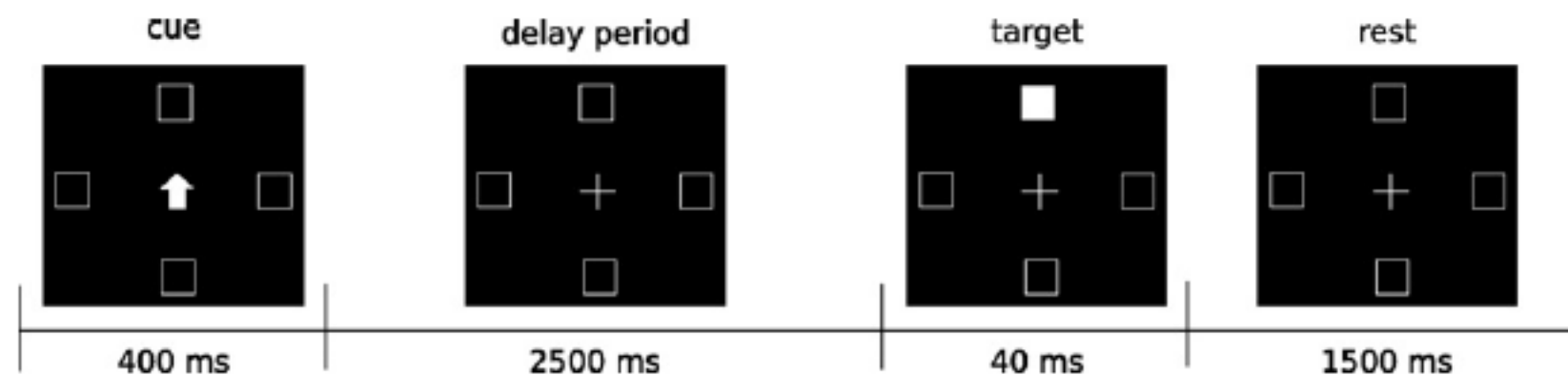
- **Alpha-World of Warcraft** (HMI, University of Twente)





## Covert visual attention: Task

- Fixating your eyes on a certain point while paying attention to another point in your visual field
- Typical experiment paradigm: Spatial Cueing Paradigm (Posner, 1980)



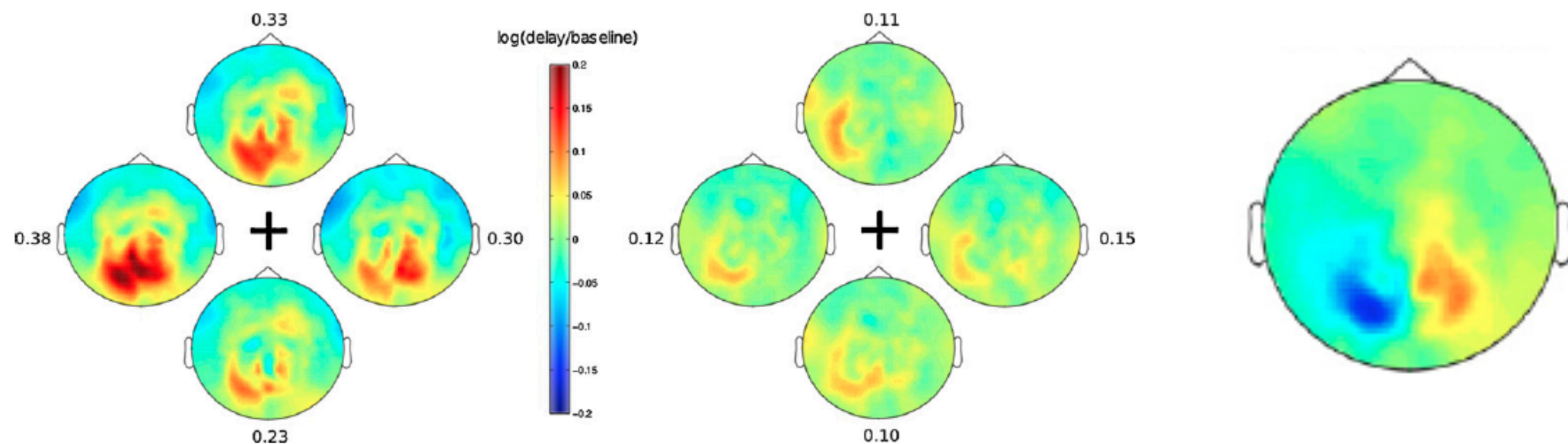
(van Gerven et al., 2009)  
(See also article P3 lecture)

- Faster reaction time when you're paying attention!



## Covert visual attention: Brain signature

- Typical brain signature coming from the **visual cortex** during expectation of a stimulus (attention period):



- Decrease contralateral in the alpha band
- Increase ipsilateral in the alpha band (Possibly caused by distractor that needs to be suppressed)

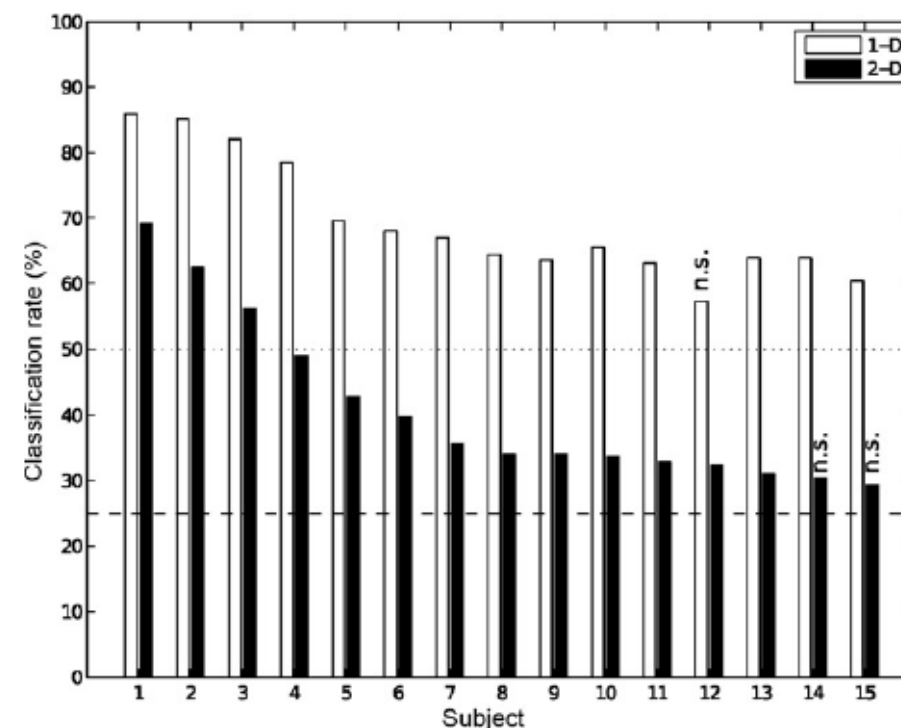
(van Gerven et al., 2009)





## Covert visual attention: Analysis

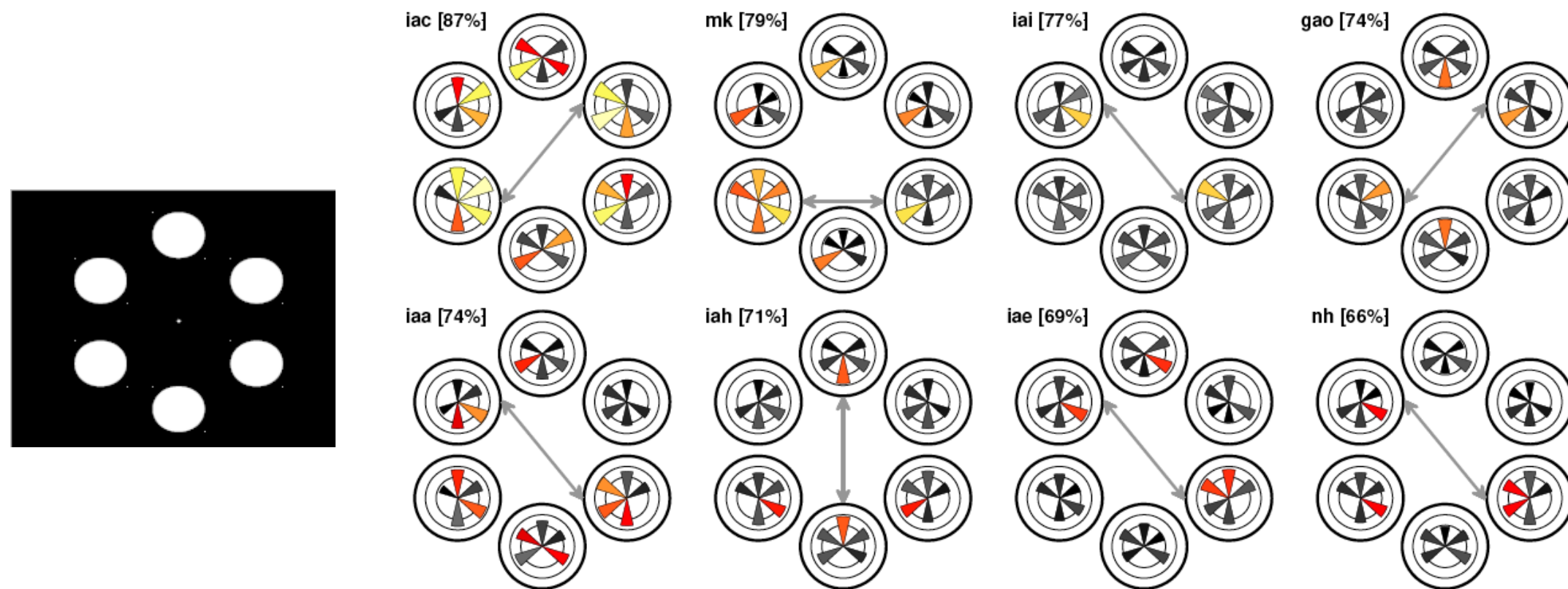
- Features:
  - **Lateralisation index** =  $\log(\text{right hemisphere alpha power}) / \log(\text{left hemisphere alpha power})$
  - Could also do similar analysis as with imagined movement
- Classification:
  - Logistic regression



(van Gerven et al., 2009)



## Covert visual attention: Variability between subjects



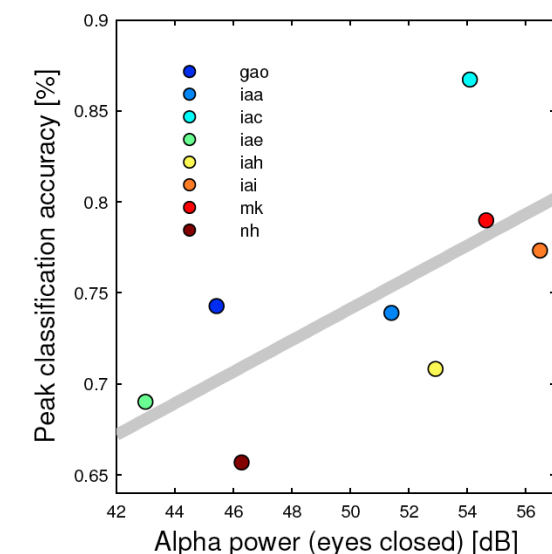
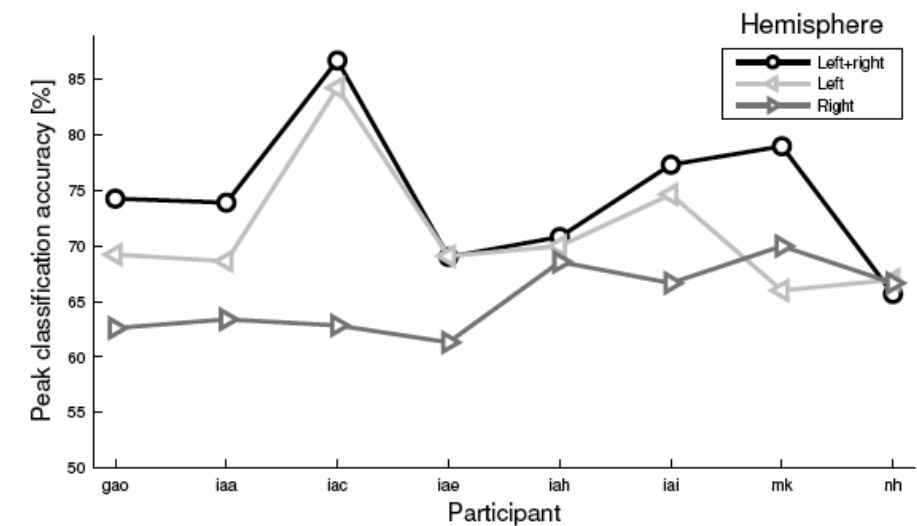
(Treder et al., 2011)



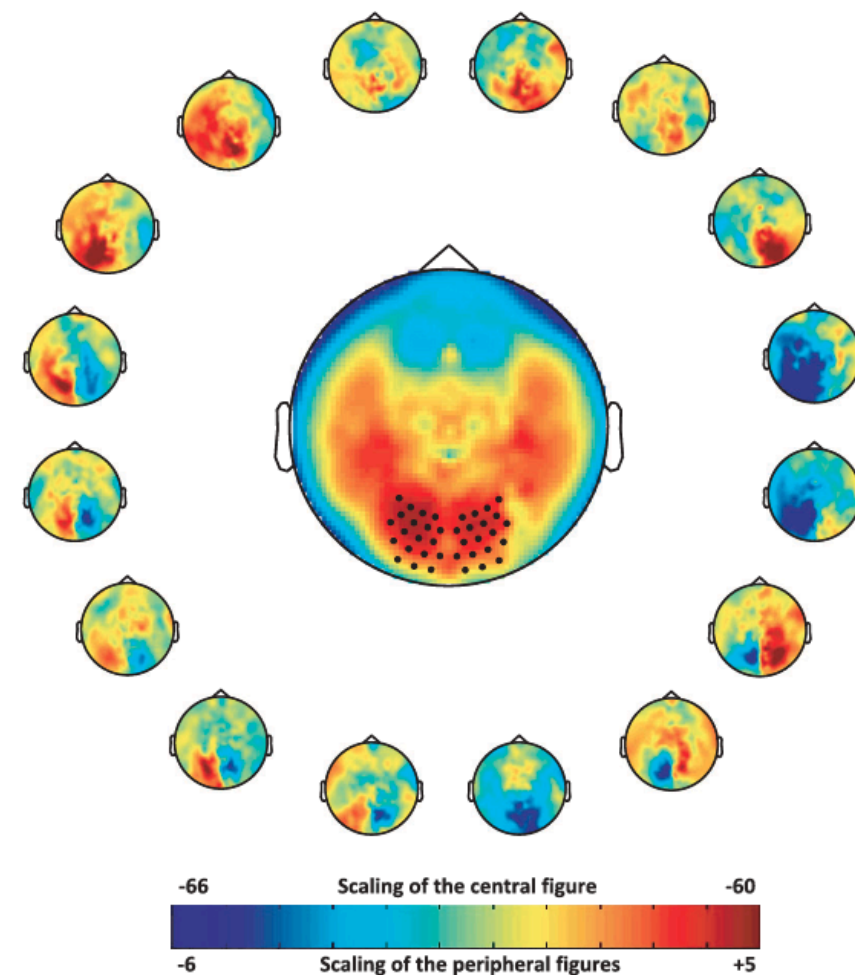
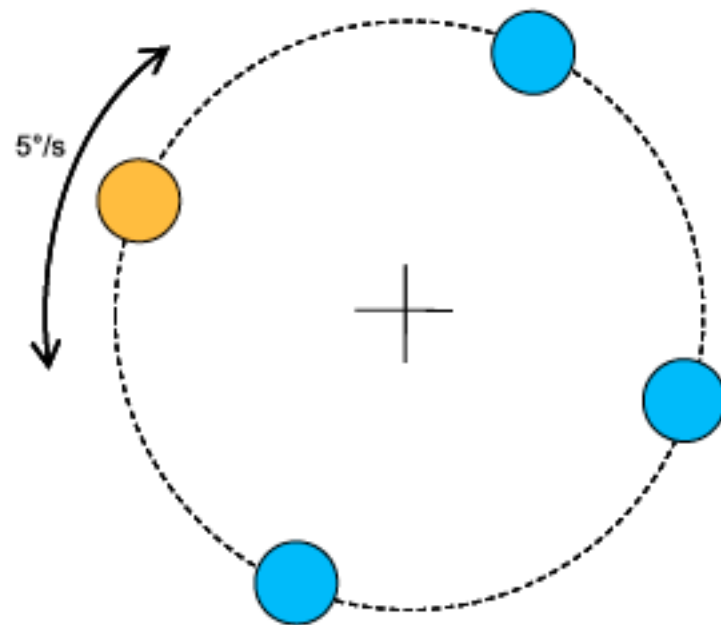
## Covert visual attention: Other

- The left hemisphere seems to be more useful for classification
- Predictor of BCI performance: if you have more occipital alpha (closed eyes) the lateralization also seems stronger! ( $r=0.63$ ) (Relaxed eyes open for imagined movement correlates as well ( $r=0.53$ ), Blankertz et al. 2010))

(Treder et al. , 2011)

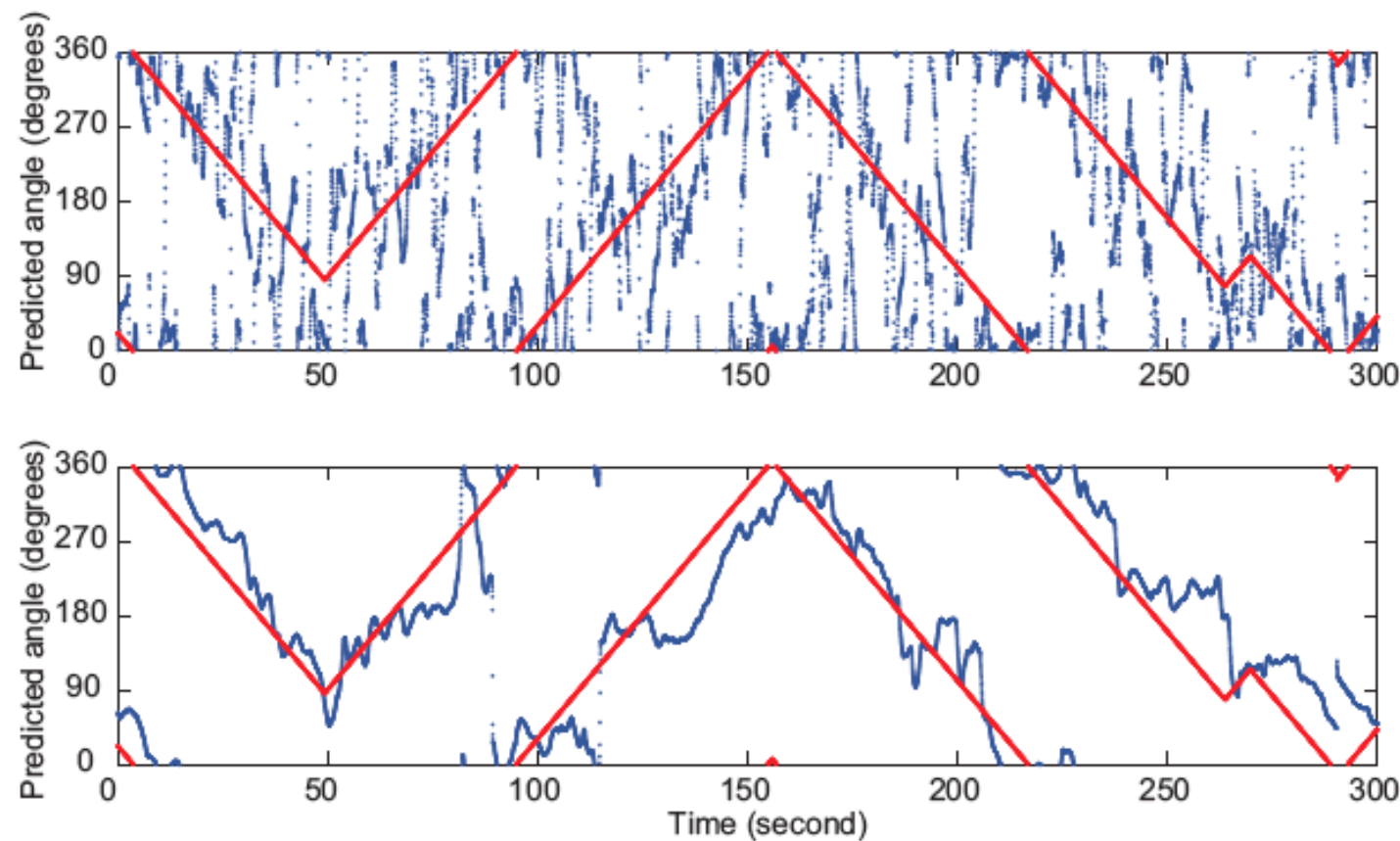


## Covert visual attention: Continuous control



Attentionotopy of the brain!  
(Bahramisharif et al., 2010)

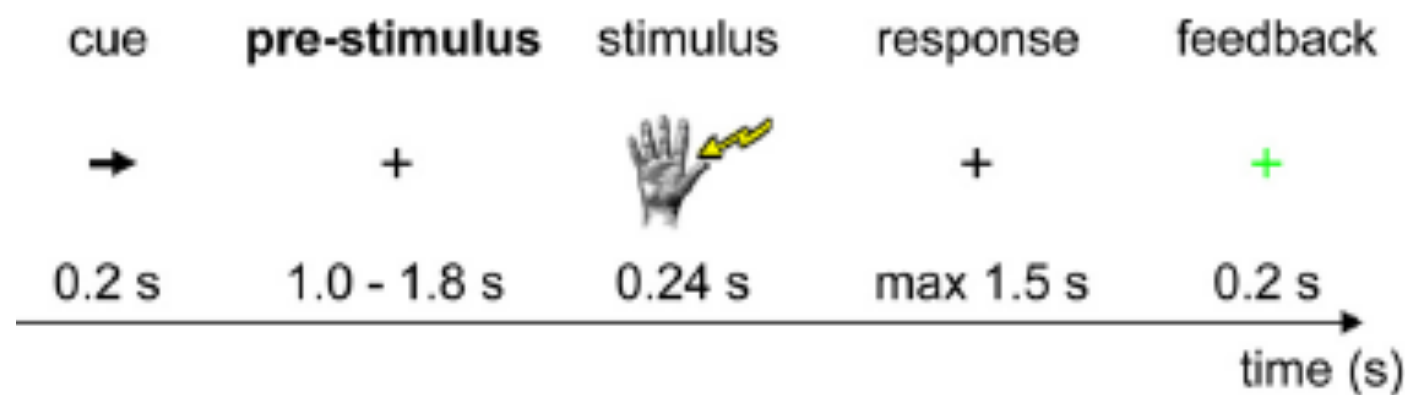
## Covert visual attention: Continuous control classification



(Bahramisharif et al., 2010)

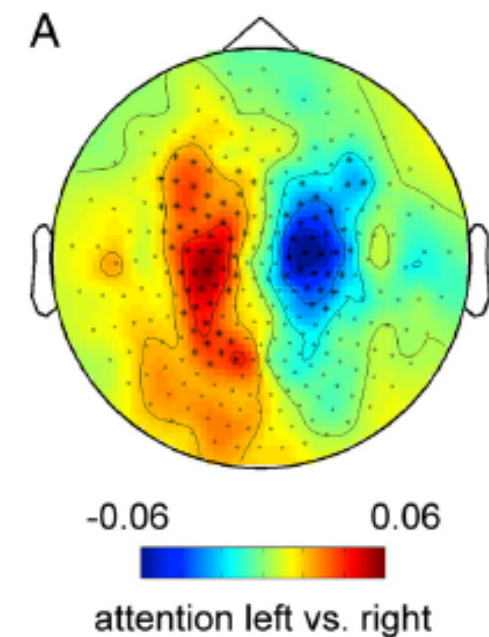
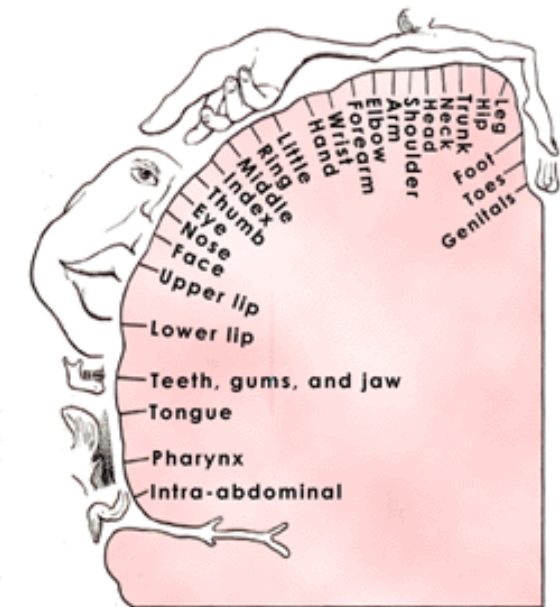
## Tactile attention

- **Task:** Focus your attention to one of your hands



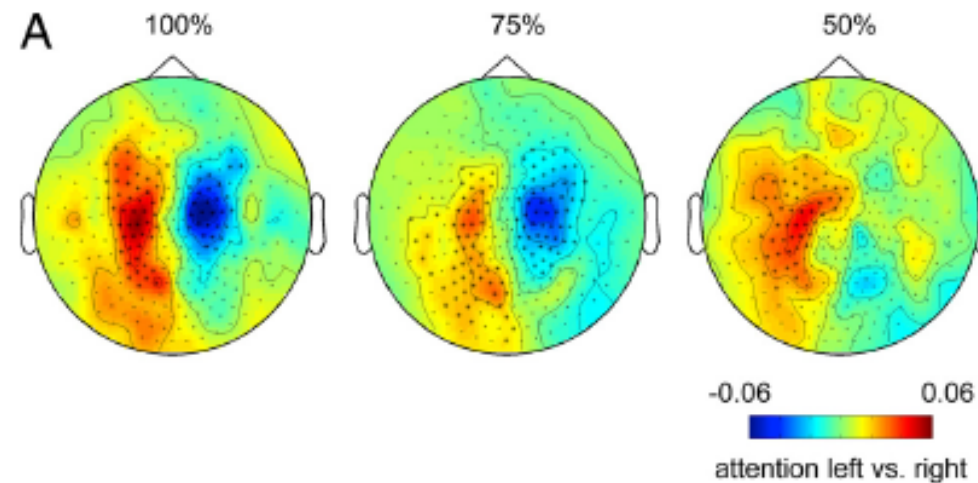
- During expectation of a tactile stimulus, there is a typical lateralization pattern in the **somatosensory cortex** (alpha band, but also beta band (**14-30Hz**)) (van Ede et al., 2010, Jones et al., 2010)

( Haegens et al., 2011)



## Tactile attention BCI

- Nothing published yet about BCI usage, but preliminary analyses show it is usable!
- Alpha reflects degree of anticipation (Haegens et al., 2011)

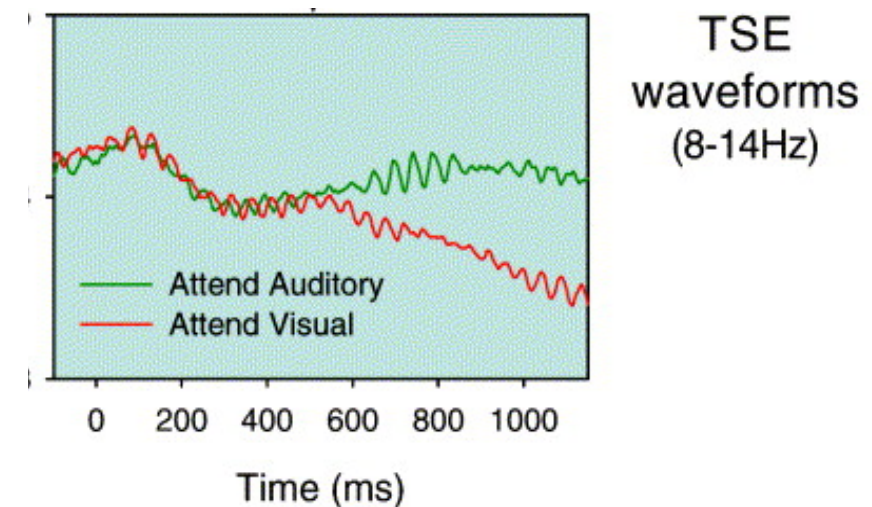
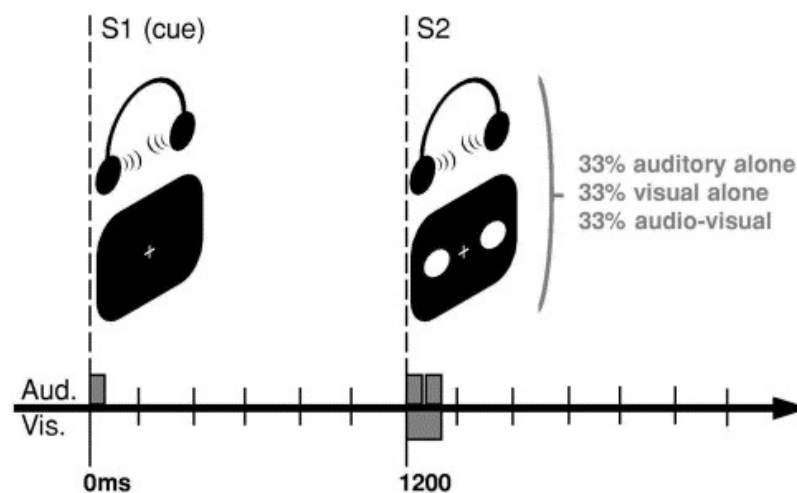


- However, also works without giving the tactile stimulus at the end (using auditory cue instead)!



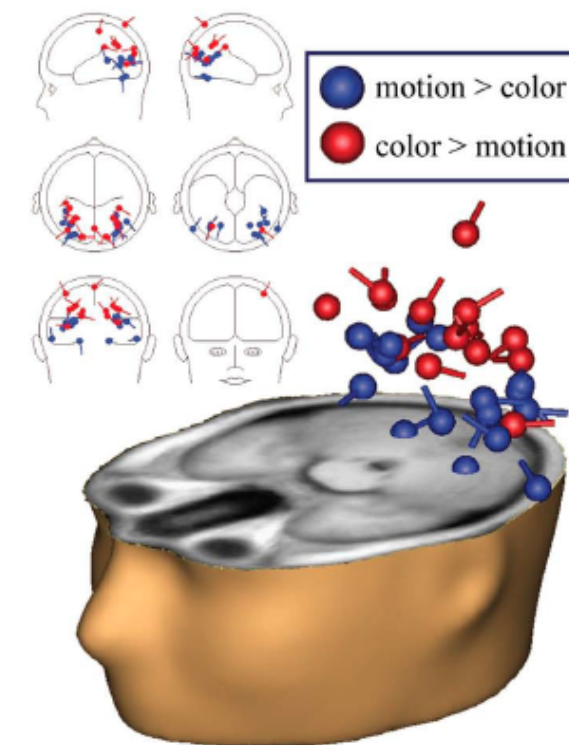
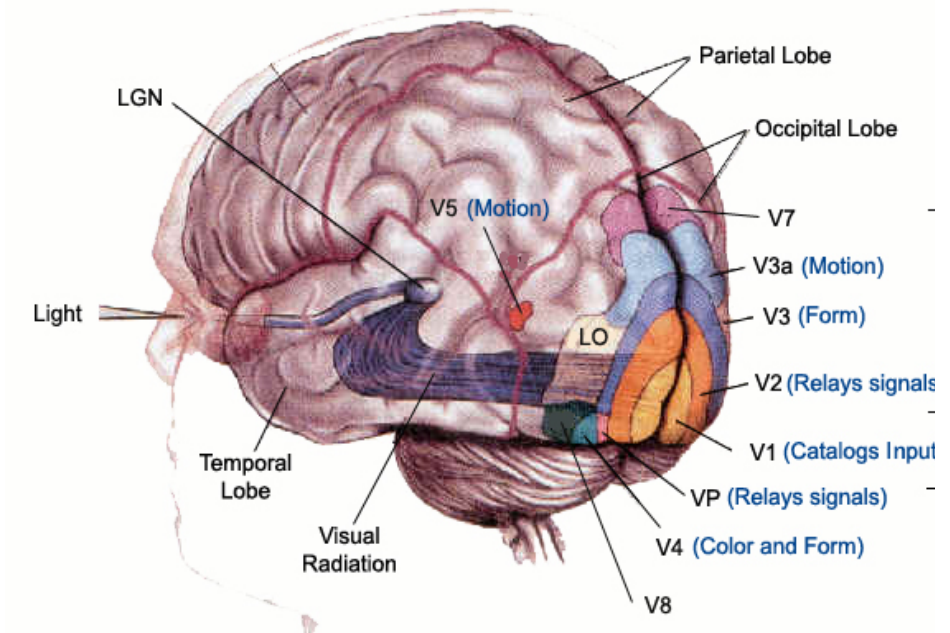
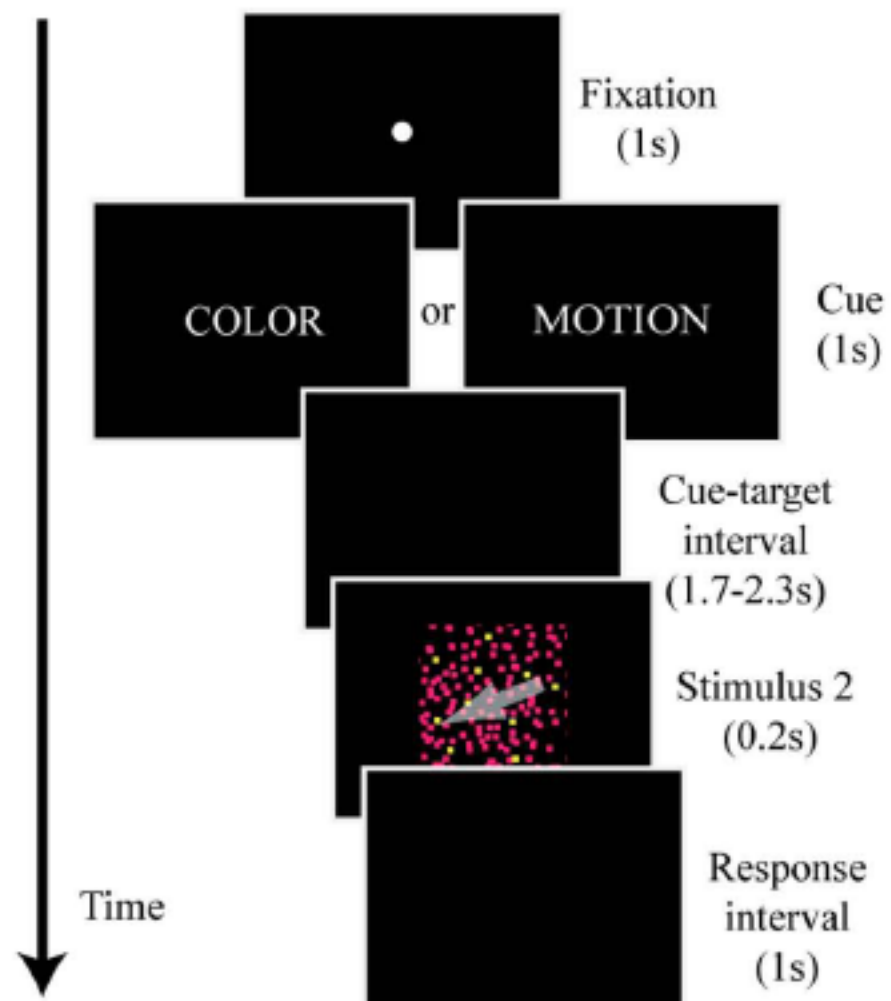
## (Covert) auditory attention

- There's a difference in alpha power when you are expecting a sound or a visual stimulus (in P3 and P4, so not lateralized!) (Fu et al., 2001)



- There also seems to be a lateralization during auditory attention (Kerlin et al., 2010, Thorpe et. al, 2011)
- Not applied in BCI yet! It is possible?

## Feature attention and alpha



(Snyder et al., 2010)



## Current/open issues for alpha BCIs

- As with all BCI's lots of variability between subjects/illiteracy
- None of them have been tested with patients yet!
- Artefacts could be involved with the signal (for example microsaccades)
- Lots of research still to do:
  - Can we change the task so that it gives a stronger signal? (for example, task difficulty, location stimulus)
  - Can we combine several attention paradigms?
  - Can we use feature (not spatial) attention?
  - Does it work with patients?

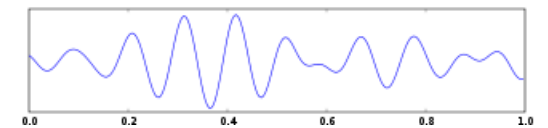






## Summary

- What is “attention”?
  - Attention is everywhere, for selecting salient information!
  - Endogenous versus exogenous attention
  - Covert versus overt attention
- Why are attention based paradigms used for BCIs?
  - Natural paradigm, no muscles involved, strong signal, possible to encode in multiple directions
- What is the alpha-rhythm and how can it be modulated?
  - 8-14 Hz, alertness/covert attention
- What are the different types of alpha based BCIs and how do they work?  
Which brain signatures do they use?
  - Relaxation BCI (WOW) (alpha power in occipito/parietal cortex)
  - Covert visual attention BCI (alpha lateralization visual cortex)
  - Tactile Attention BCI (alpha lateralization sensorimotor cortex)
  - Others possibilities: auditory, feature, combined
- What are the open issues? (answered in previous slide)





## References

- Review articles:
  - **Required:** O. Jensen, A. Bahramisharif, R. Oostenveld, S. Klanke, A. Hadjipapas, Y.O. Okazaki, M.A.J. van Gerven, *Using brain-computer interfaces and brain-state dependent stimulation as tools in cognitive neuroscience*, *Frontiers in Psychology*, May 2011.
  - **Recommended:** J.J. Foxe, A.C. Snyder, *The role of Alpha-band brain oscillations as a sensory suppression mechanism during selective attention*, *Frontiers in Psychology*, July 2011.
- Visual covert attention:
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  - J.R. Kerlin, A.J. Shahin, L.M. Miller, *Attentional gain control of ongoing cortical speech representations in a “cocktail party”*, Journal of Neuroscience, 2011
  - S. Thorpe, M. D’Zmura, R. Srinivasan, *Lateralization of frequency-specific networks for covert spatial attention to auditory stimuli*, Brain Topography, 2011
- Feature attention:
  - A.C. Snyder, J.J. Foxe, *Anticipatory attentional suppression of visual features indexed by oscillatory alpha-band power increases: a high-density electrical mapping study*, Journal of neuroscience, 2010

