

# PHILIPS

sense and simplicity

## Stimulation Effects in SSVEP-based BCIs

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Brain, Body & Behavior

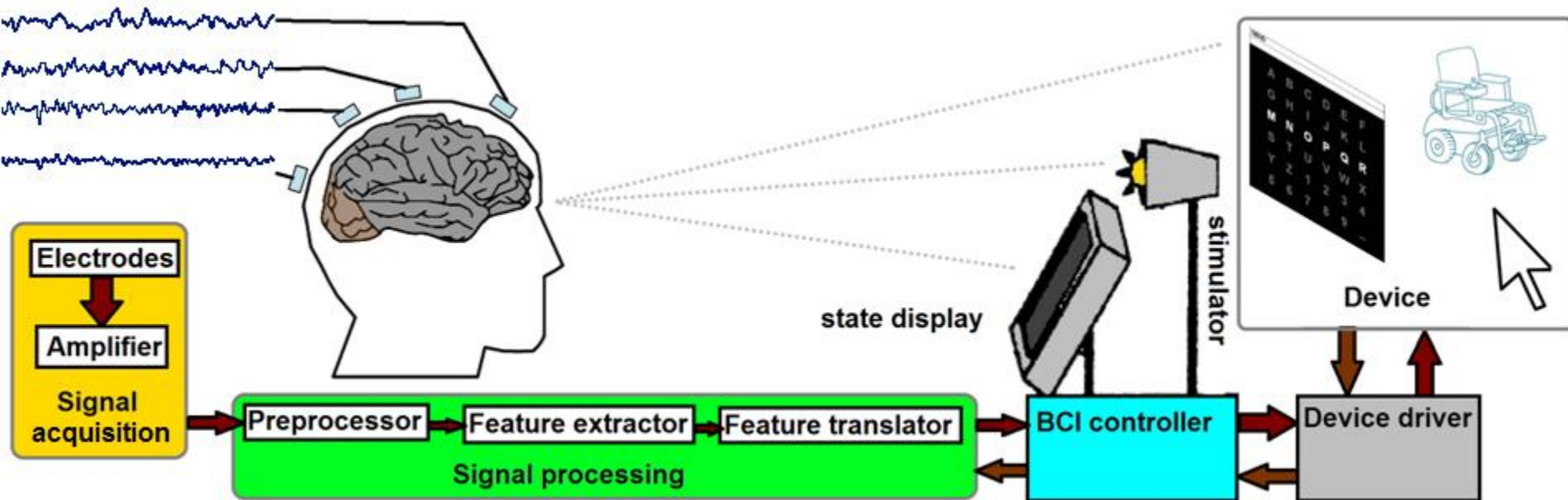
June 18, 2010

# Outline

- Brain-Computer Interfaces (BCIs)
- Steady-state visual evoked potential (SSVEP)
- SSVEP-based BCIs
- Stimulation properties
- Conclusion
- Questions

# Brain-Computer Interface

- *A brain-computer interface (BCI) is a system that allows a user to communicate his intent to a system without using any peripheral output pathways.*



# Measures of success

Performance

$$ITR = C * \log N / T$$

o  
r  
r  
e  
c  
t  
  
r  
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m  
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( $\Sigma$ )



Comfort

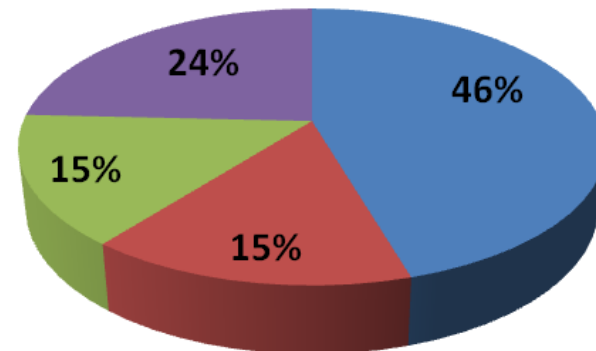
Questionnaire

# BCI Types

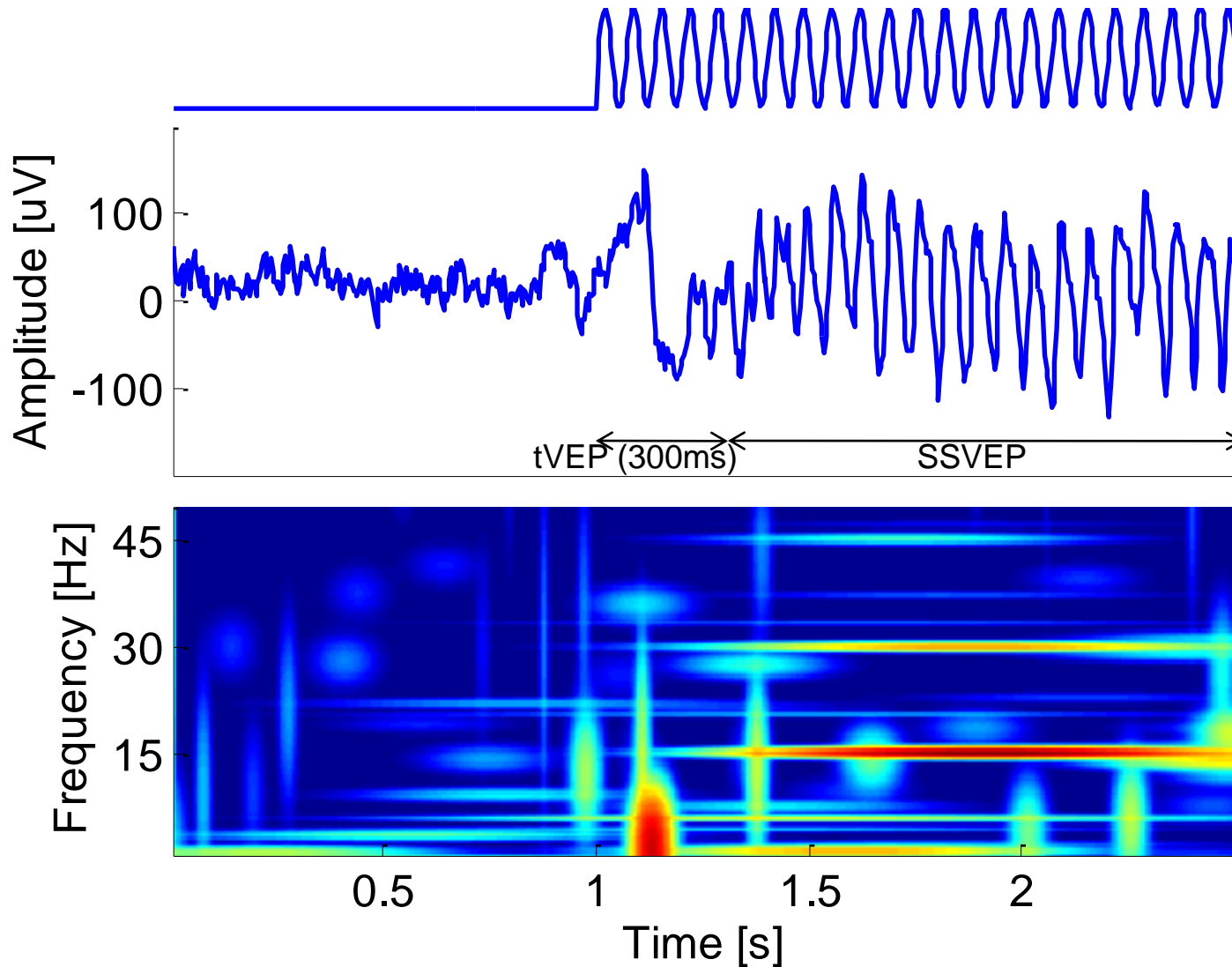
- BCIs can be based on different neuromechanisms.
  - Sensorimotor activity
  - P300 / oddball paradigm
  - Visual evoked potentials
- BCIs based on the steady-state visual evoked potential appear to be especially promising.

**BCI Neuromechanisms**

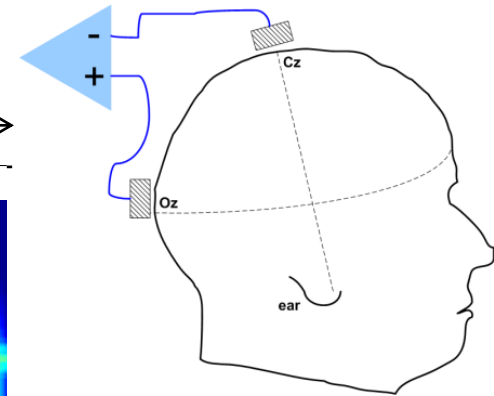
■ Sensorimotor activity ■ VEP ■ P300 ■ Other



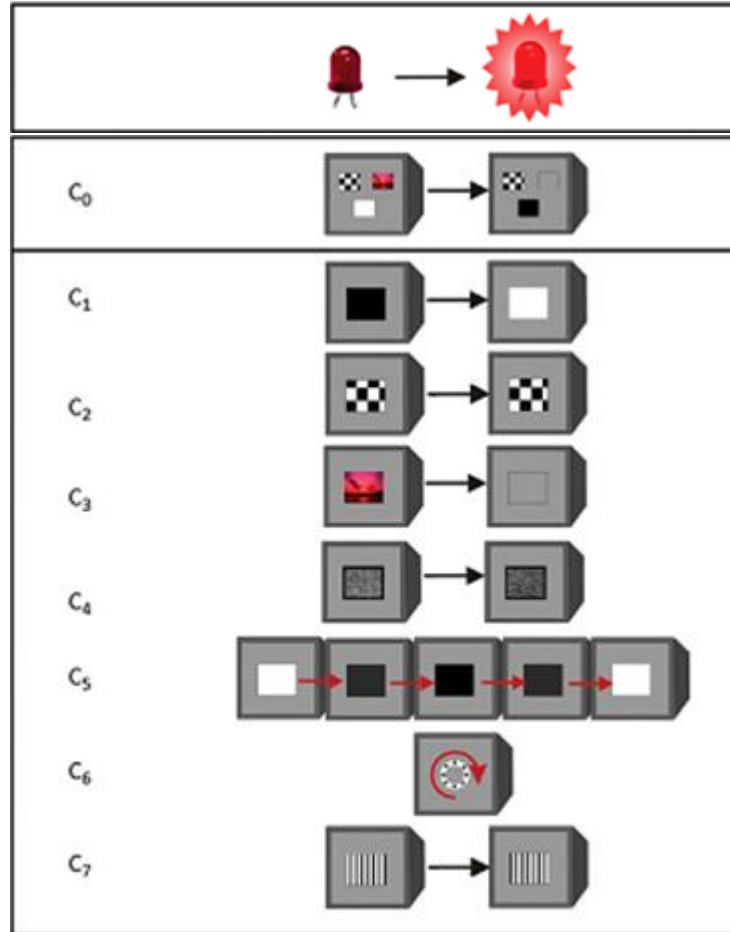
# Steady-state visual evoked potential



Oscillatory light intensity (15 Hz)

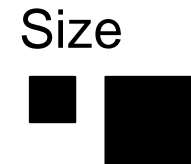
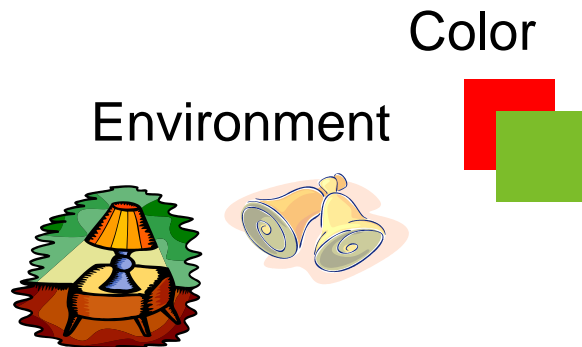
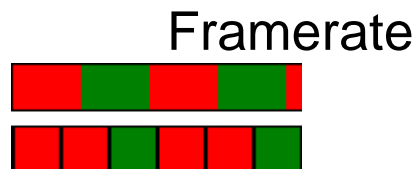
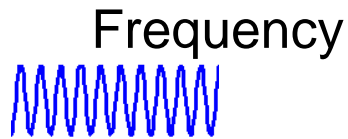


# Stimulation



# Goal

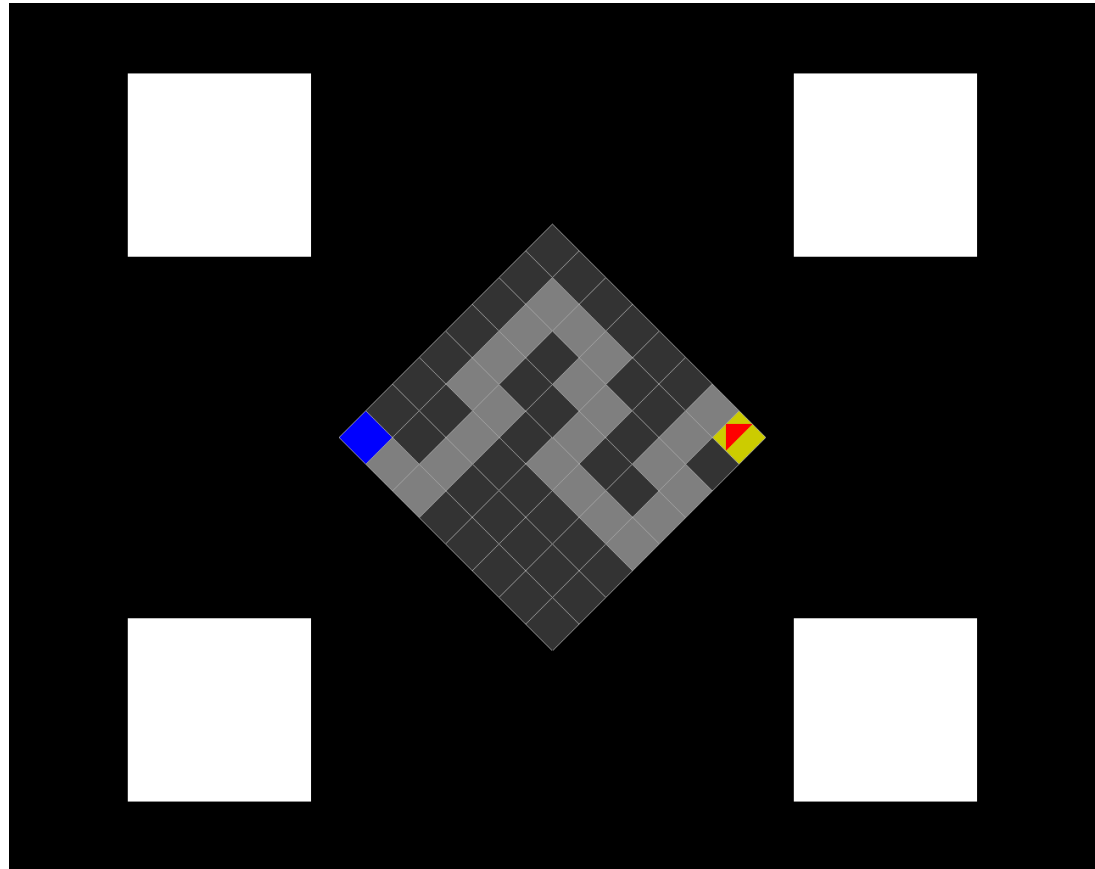
***To determine the optimal stimulation properties to improve the performance and comfort of SSVEP-based BCIs.***





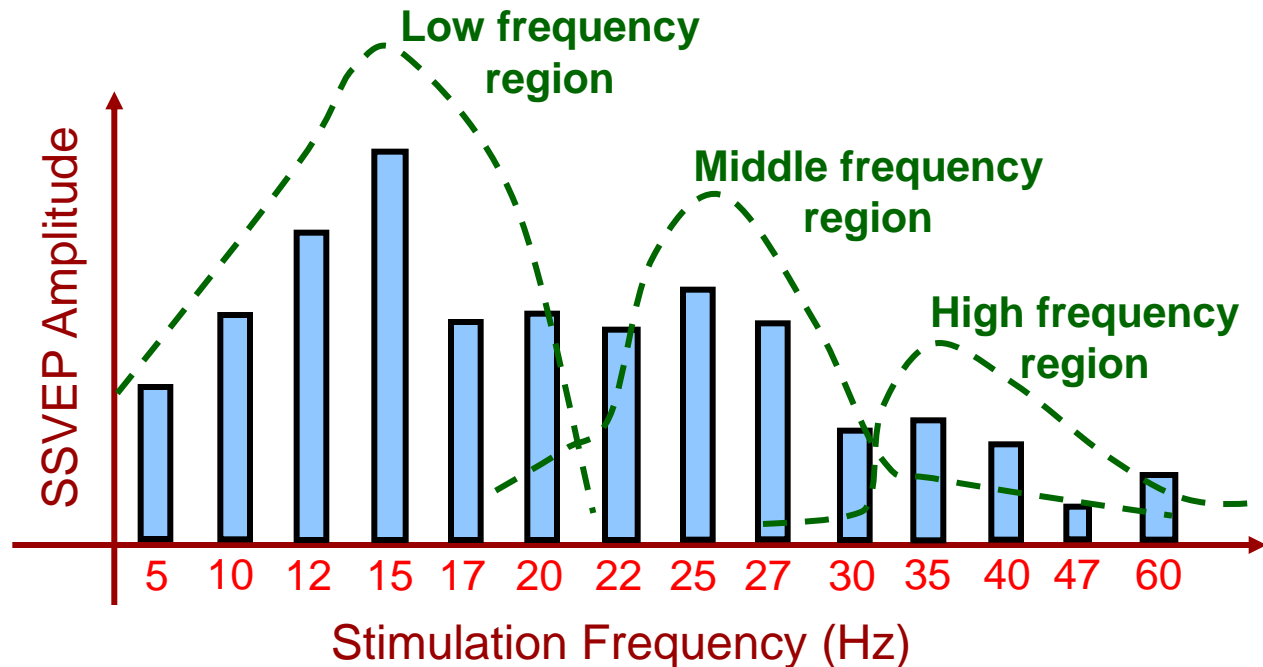
# SSVEP-based BCI: maze navigation

- BioSemi
- BCI 2000
- Neurostim
  
- 6 subjects



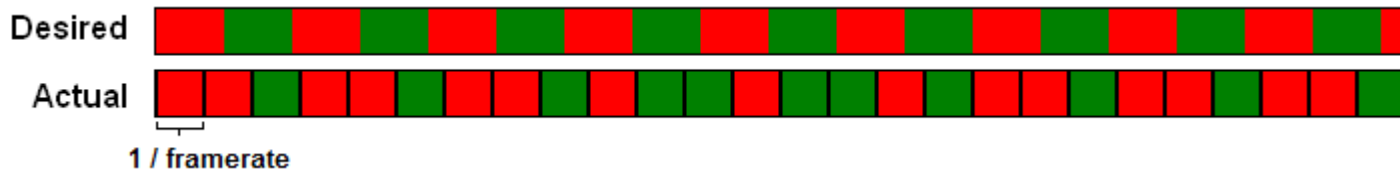
# Frequency

- The strength of the SSVEP response depends on the stimulation frequency.
- Higher frequencies are more comfortable to look at and are less likely to induce epileptic seizures.

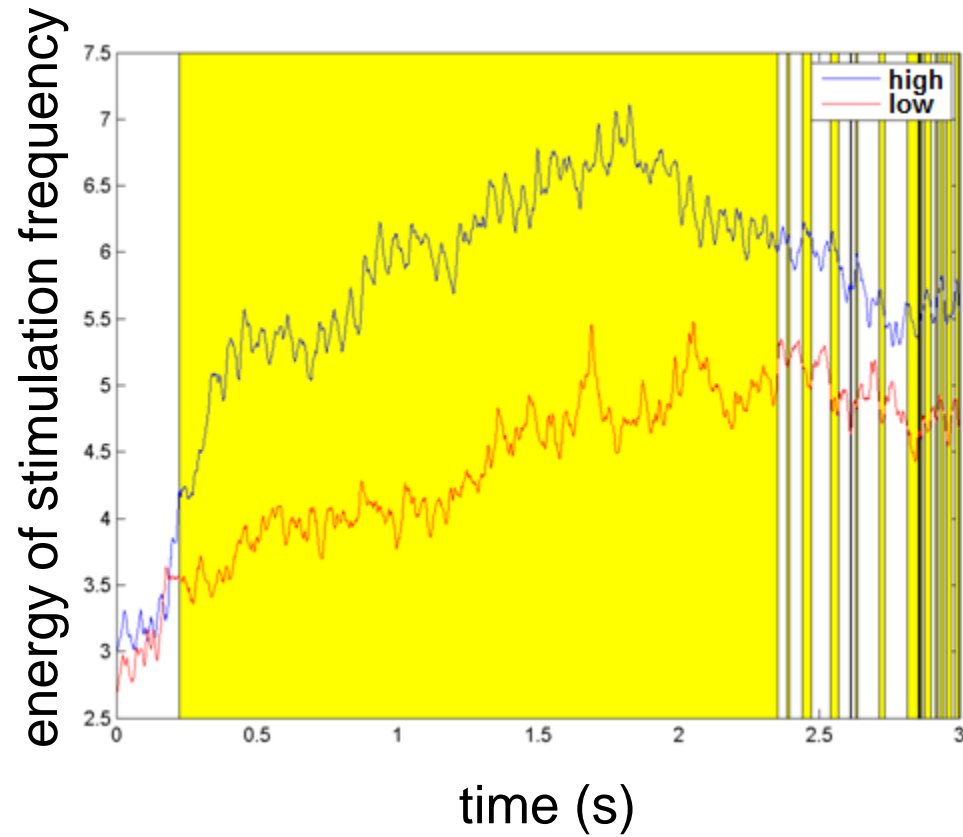
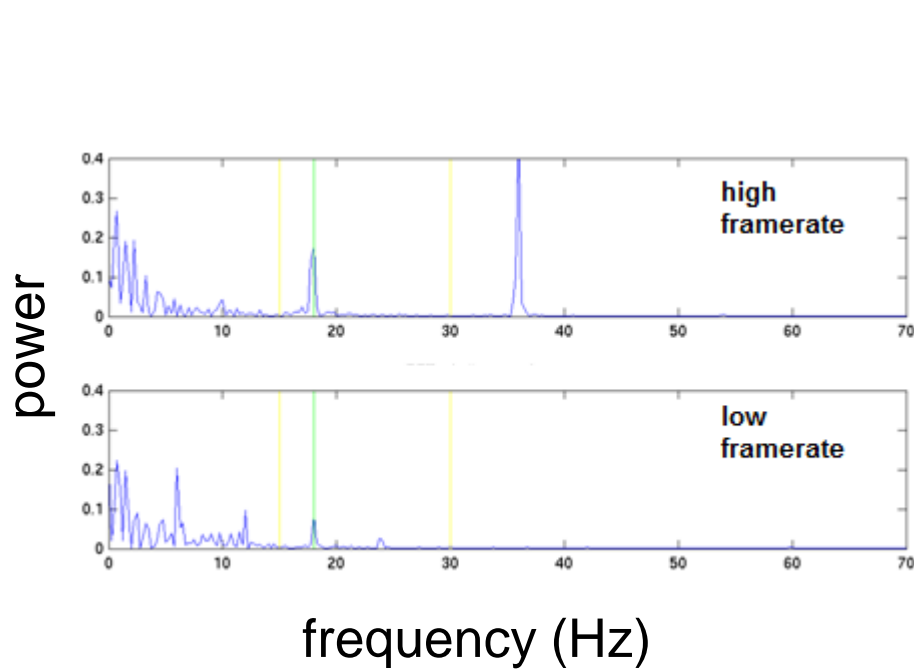


# Framerate

- Which frequencies can be rendered depends on the framerate of the stimulation device (and the number of intermediate states required for the waveform).
- Assuming that the minimum of 2 states are required (on/off), the device can render all frequencies  $1/kF$ , where  $F$  is the framerate and  $k$  is any integer  $> 2$ .
- If both states should be displayed an equal amount of time (duty cycle 50%),  $k$  needs to be an *even* integer  $> 2$ .

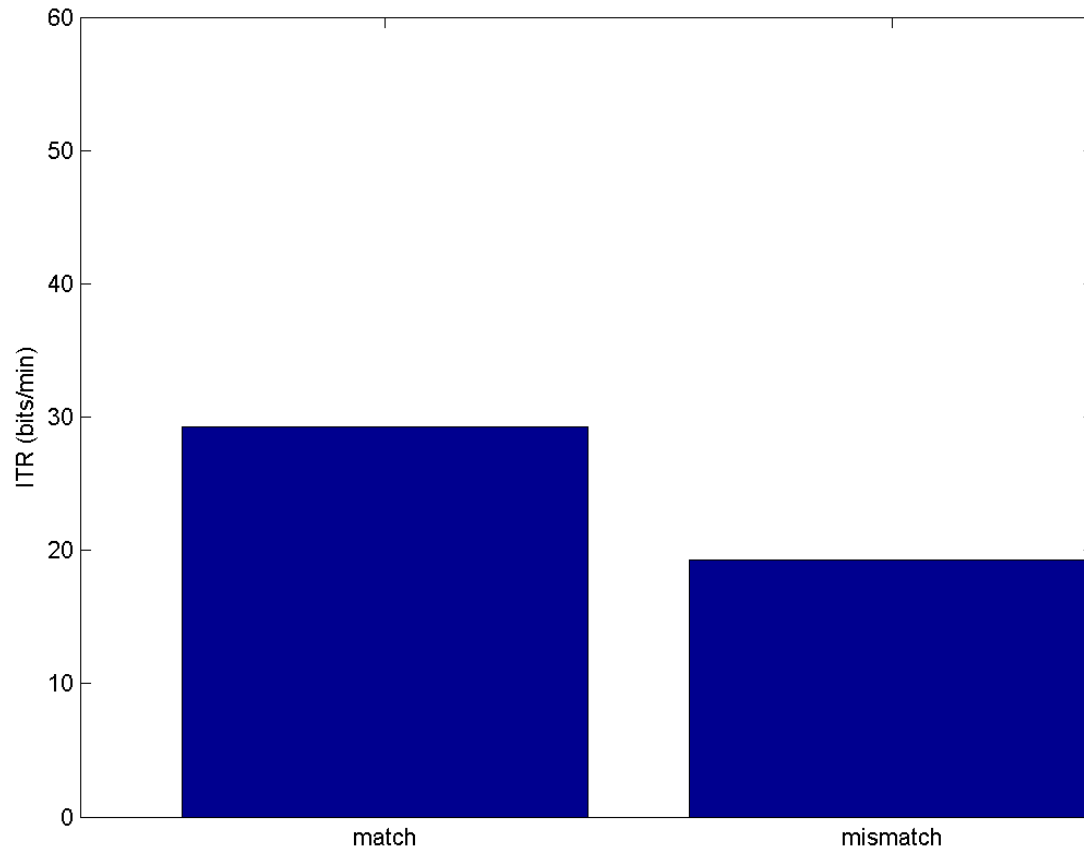


# Framerate



S4 18Hz

# Framerate

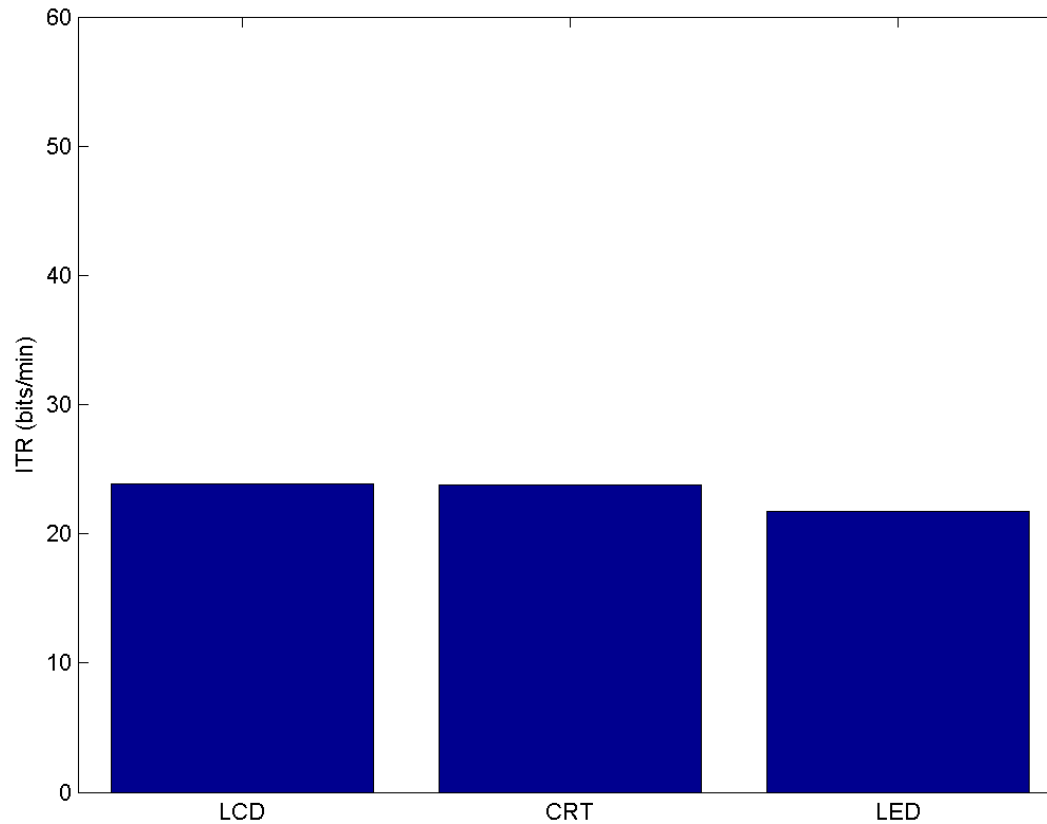


# Display device

- The most often used display devices are light emitting diodes (LEDs), cathode ray tubes (CRTs) and liquid crystal displays (LCDs).

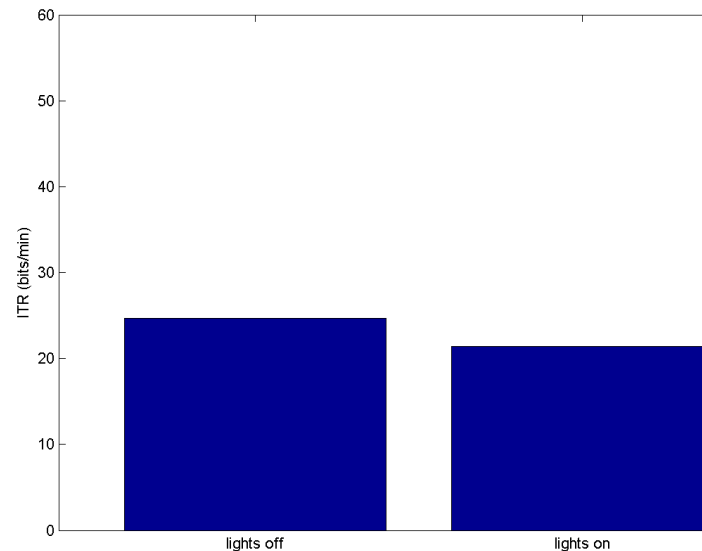


# Stimulation devices



# Environment

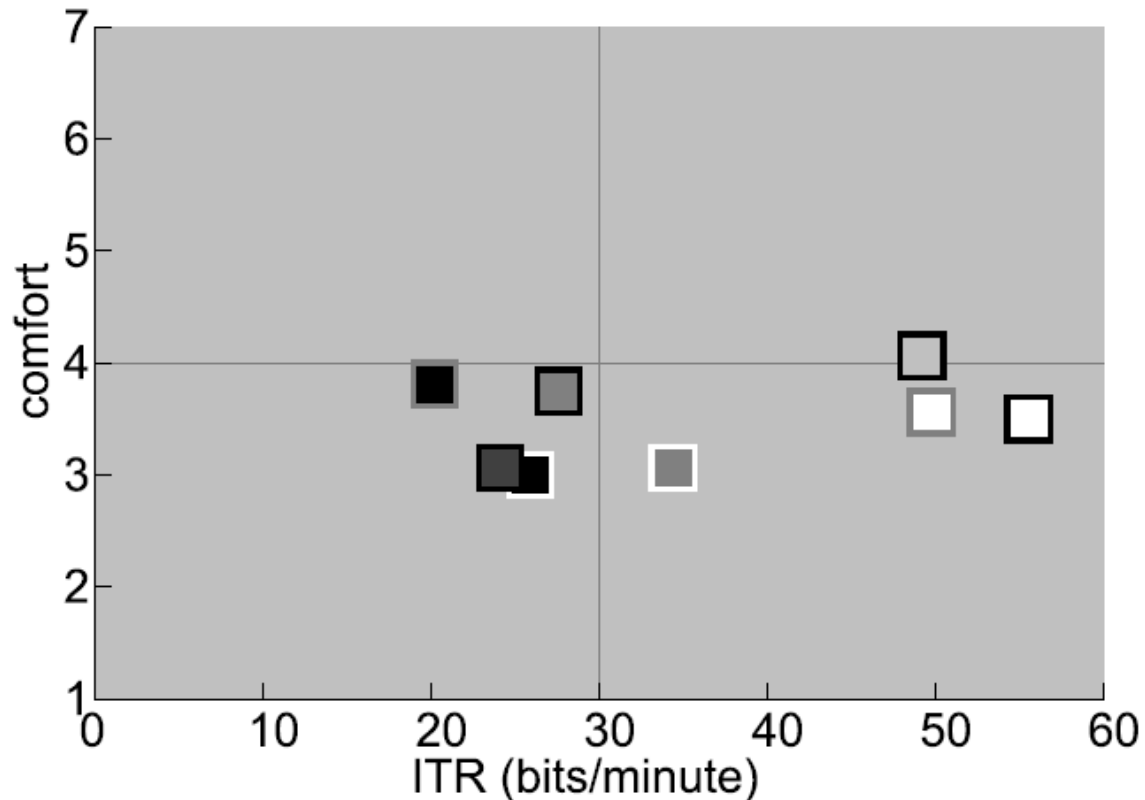
- Noise and light can have an effect on concentration and on how the stimulation is perceived.
- Frequencies of light and sound in the environment could interfere with the SSVEP response.
- In the dark, the eye becomes more sensitive to luminance changes.





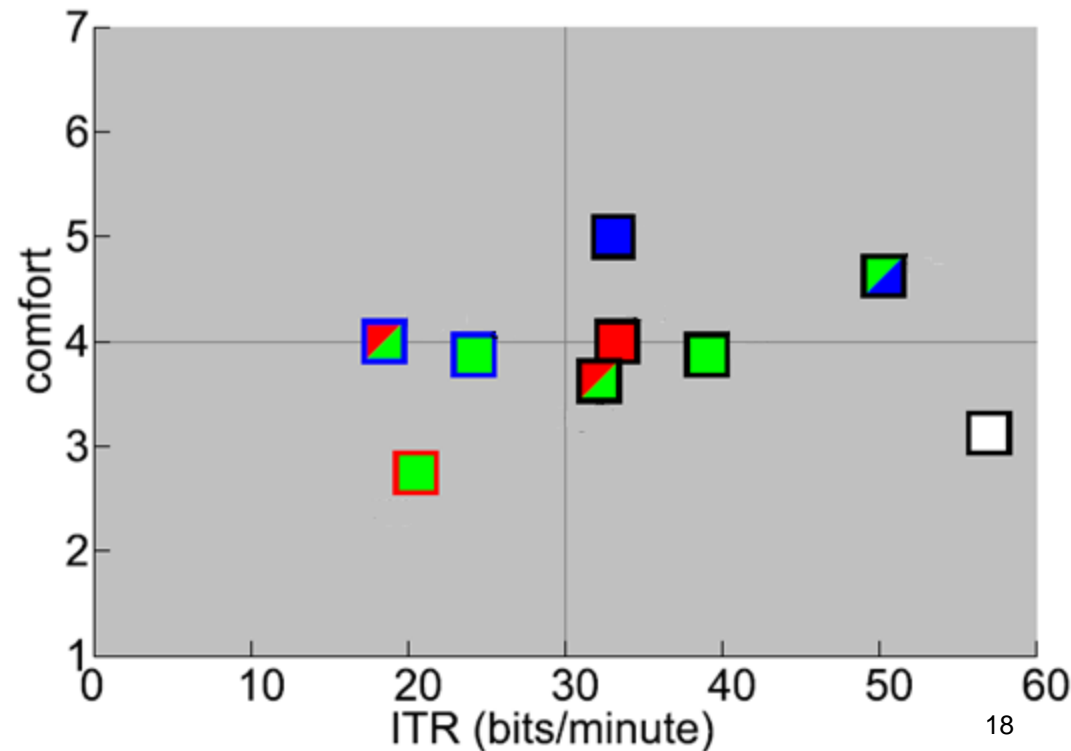
# Luminance and contrast

- The contrast of the stimulation is the most important factor in how noticeable the changes are.
- More noticeable flicker elicits stronger responses, but be less comfortable.



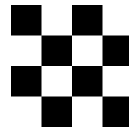
# Color

- Different colors are processed slightly differently in the eyes and brain.
- Instead of varying luminance, hue and saturation can also be alternated.
- Green-blue stimulation works really well.
- Colored backgrounds don't.



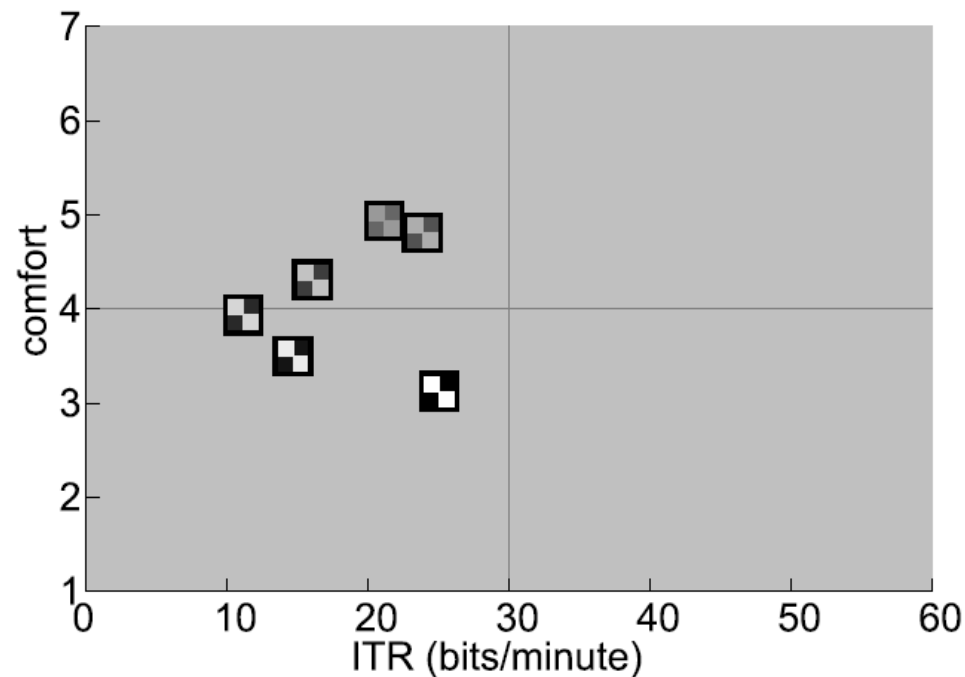
# Pattern reversal

- The checkerboard is a rectangle that is made up of smaller rectangles with alternating colors that switch around at every alternation.
- Some people say that using a checkerboard pattern elicits a larger SSVEP response.
- Contrary to the case where there is no pattern, the luminance does not have to change when the number of checks of both colors is equal.
- Also, the SSVEP response is at the alternation rate, or twice the cycle frequency, of the stimulus.



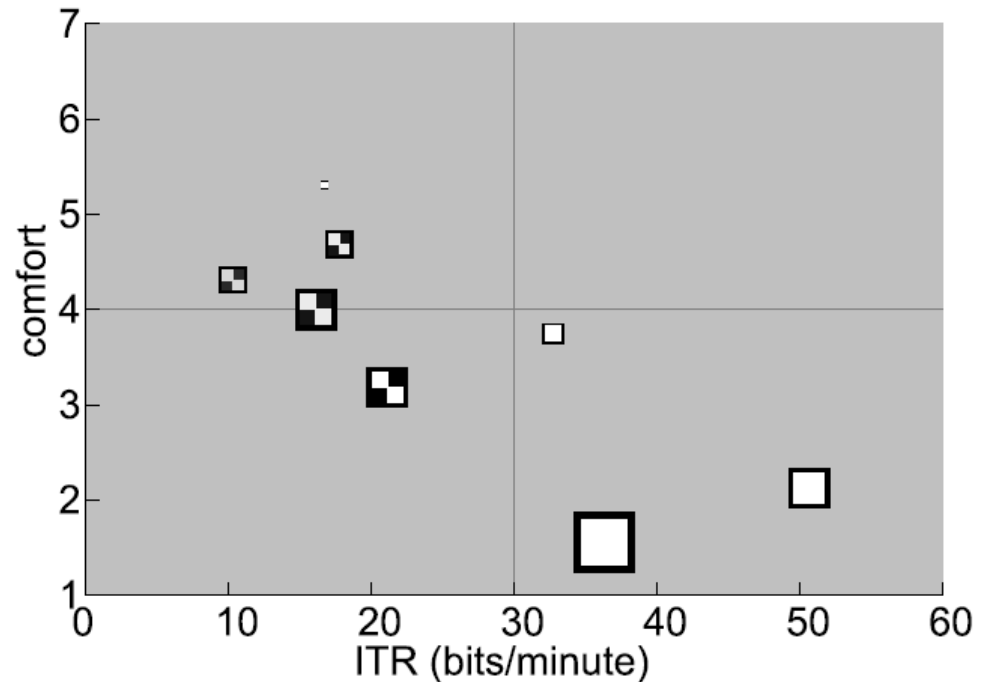
# Pattern reversal and spatial frequency

- The spatial frequency of a stimulus defines how many times the pattern is repeated in a certain space.
- A higher spatial frequency results in more and smaller cells, and has been linked to low contrast stimuli.
- Higher spatial frequencies were more comfortable, but the relation between spatial frequency and performance is nonlinear.
- Performance of pattern reversal was worse than single graphic stimulation.



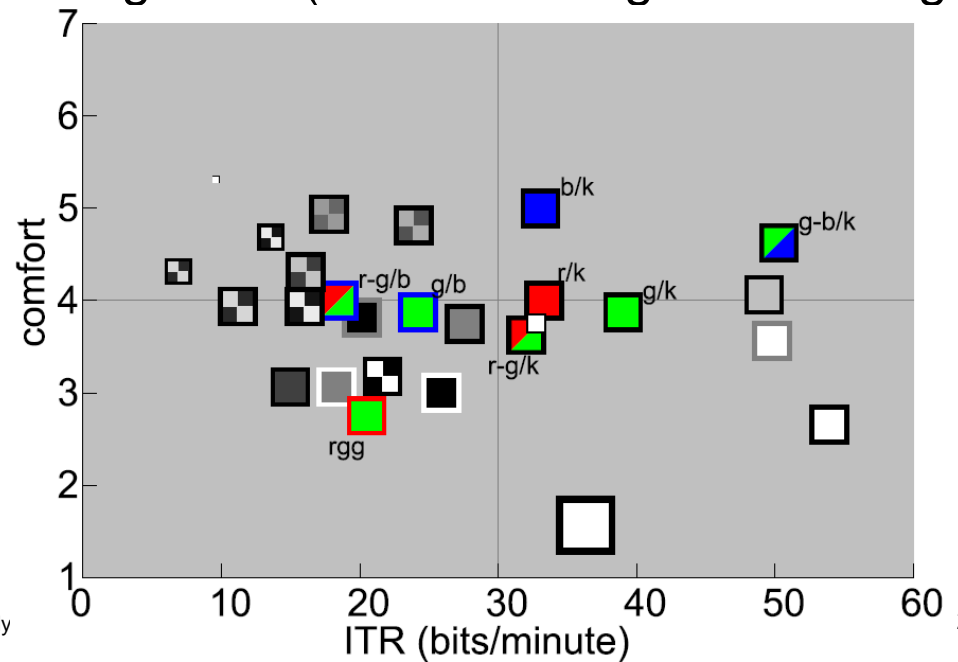
# Size

- The larger the stimulus, the more easy it is to see.
- This can increase SSVEP strength, both when the stimulus is attended to and when it's not.
- This means there is an optimal stimulus size, that is likely also influenced by target spacing.



# Conclusions

- Stimulation properties can have a significant impact on BCI performance and user comfort.
- Generally stimuli with a higher contrast are less comfortable, but result in better BCI performance.
- Stimuli that had good results on both measures are green/blue, gray and blue stimulation on a black background (with red and green coming close).



# Thanks!

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