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sense and simplicity

Stimulation Effects in SSVEP-based BCIs

Jordi Bieger, Danhua Zhu and Gary Garcia Molina

Presented by:
Tsvetomira Tsoneva

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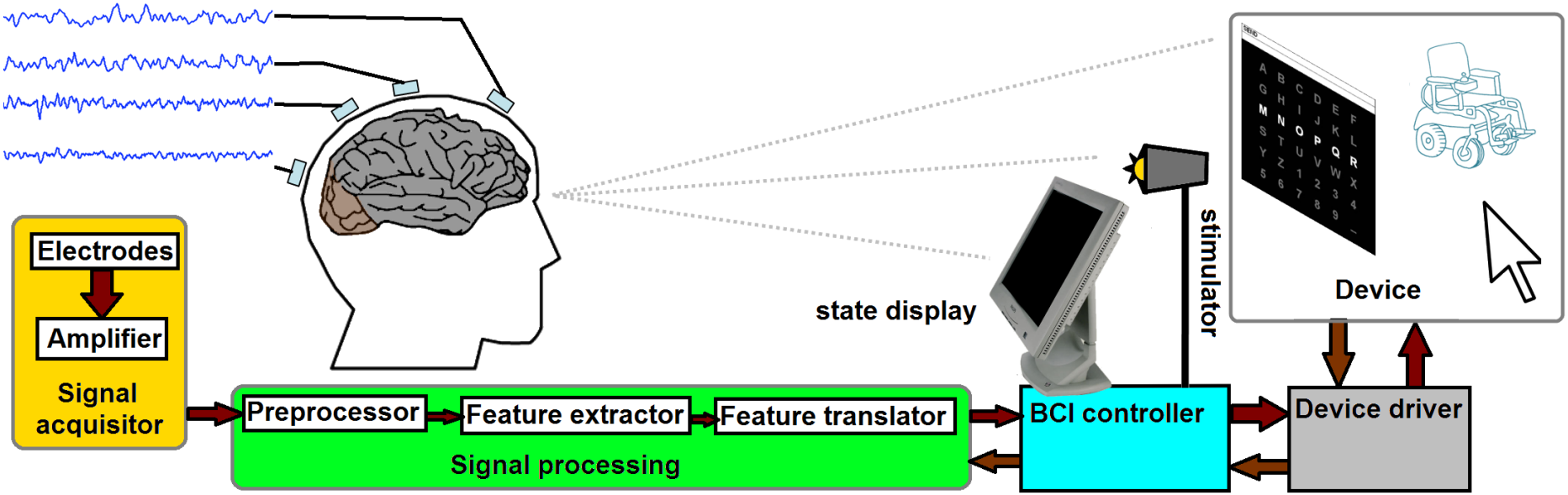
Outline

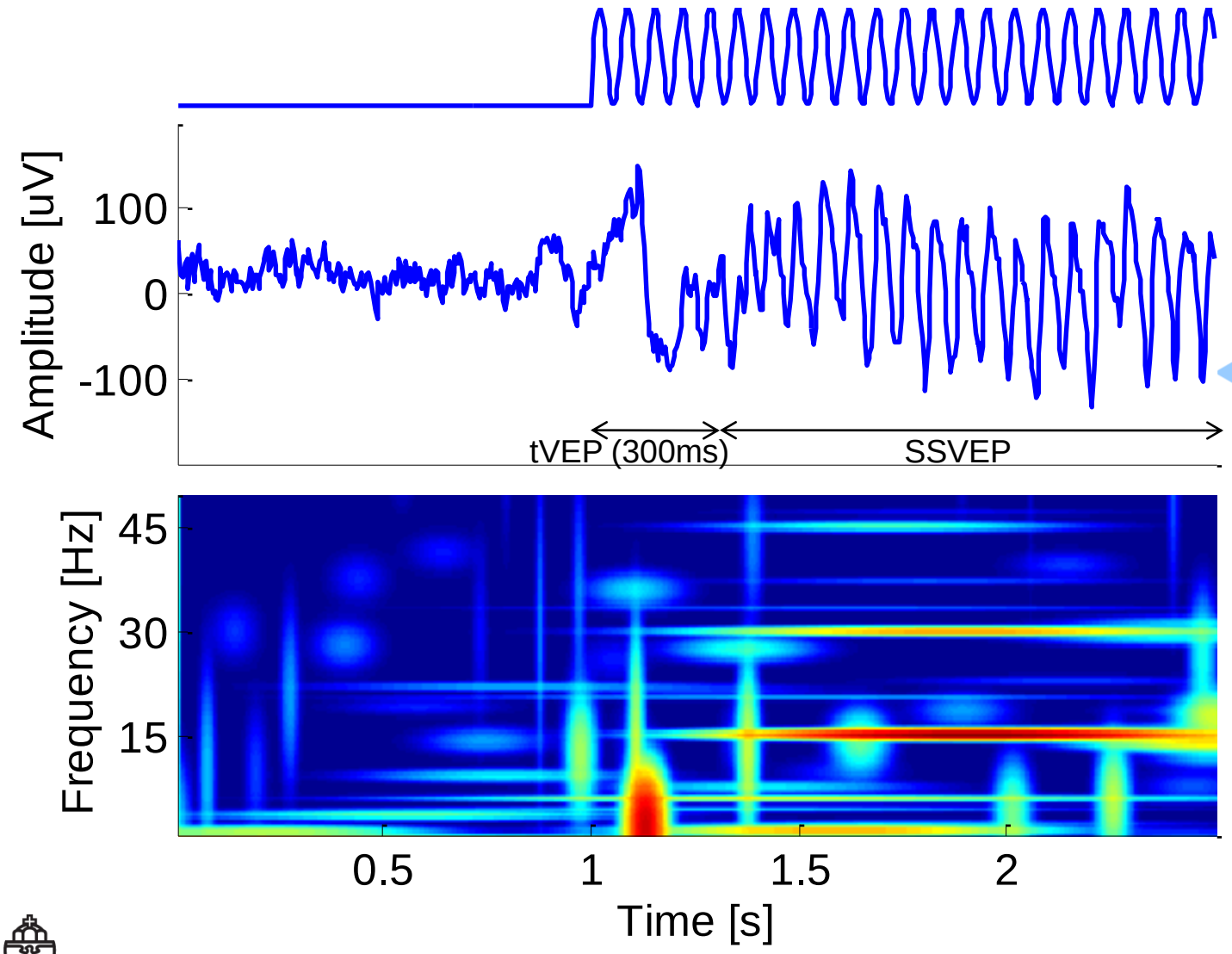
- Introduction
- Aim
- Methods
- Stimulation properties
- Conclusion
- Questions

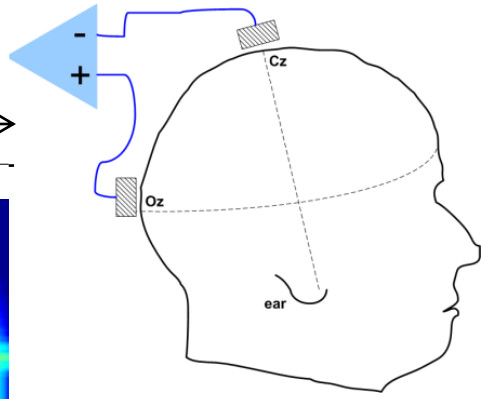
Brain-Computer Interface

- *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.*



Steady-state visual evoked potential (SSVEP)





Aim

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

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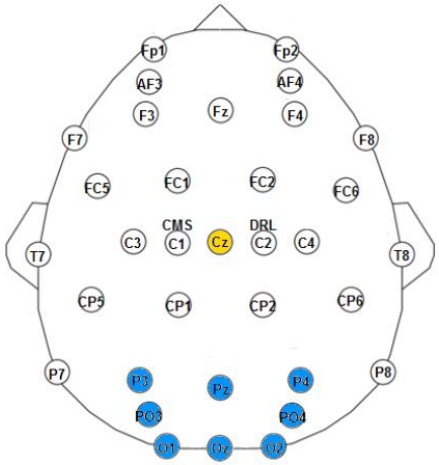
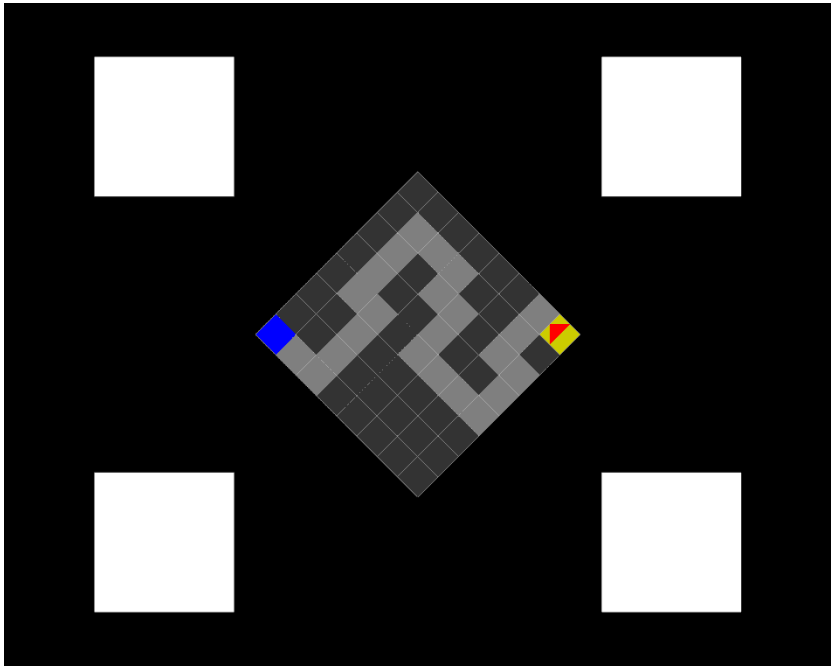
SSVEP-based BCI: maze navigation

- 10 subjects
- 6 per experiment

- Performance: ITR (bits/min)
- Comfort: Questionnaire

- BioSemi
  - 8 channels
  - + 1 reference

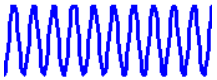




- Tools: BCI 2000, Neurostim

Stimulation properties

Frequency



Contrast

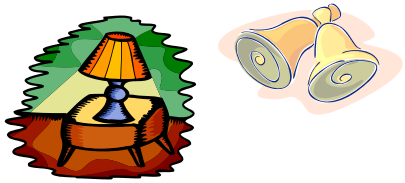
Framerate

Color

Stimulation device

Spatial frequency

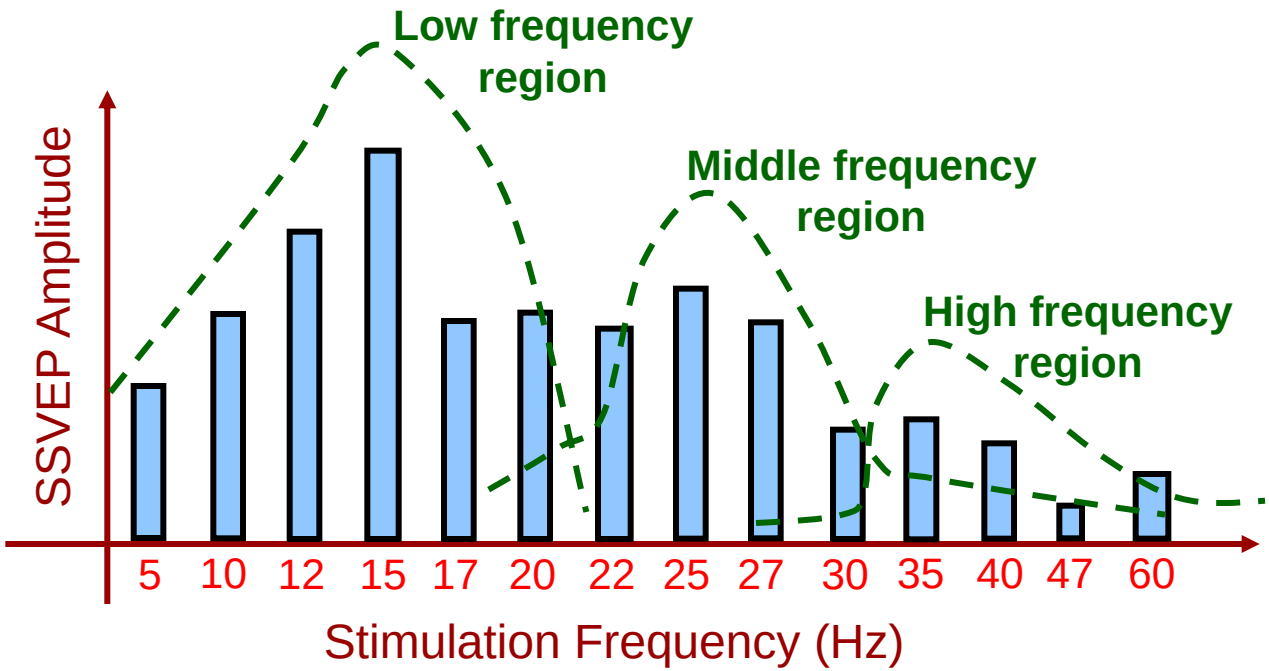
Background illumination



Size

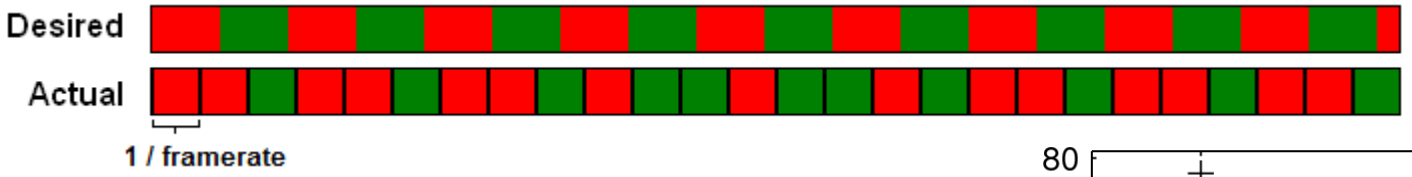
Frequency

- The strength of the SSVEP response depends on the stimulation frequency.
- We focused mostly on the lower frequency region because it allows for better comparisons between stimulation devices.

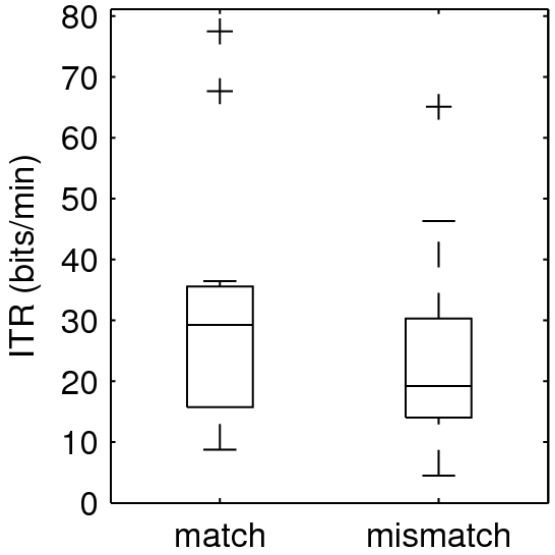


Framerate

- Which frequencies can be rendered depends on the framerate of the stimulation device (and the number of intermediate states required for the waveform).



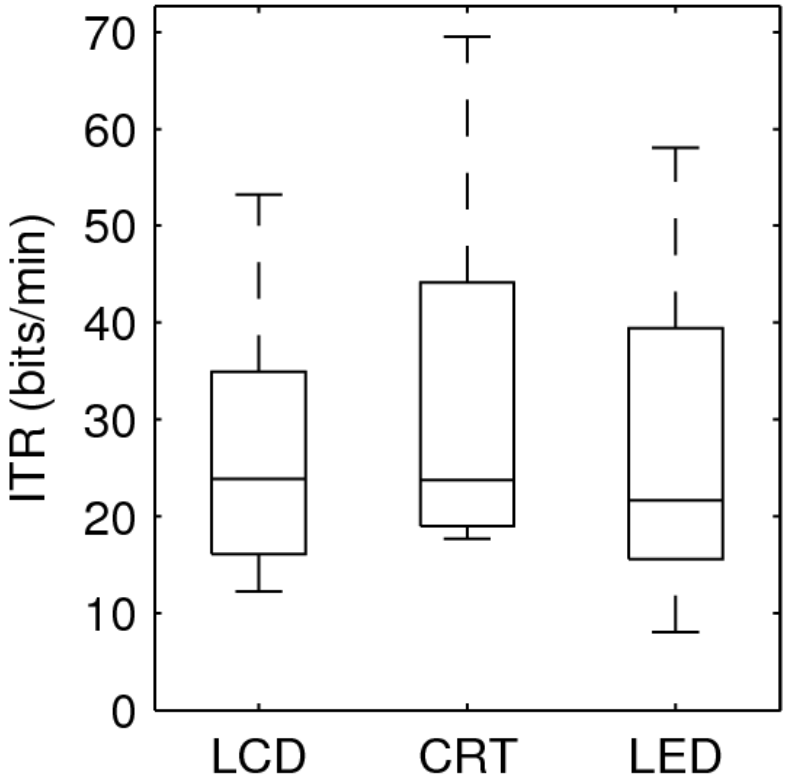
		LCD refresh rate	
		60 Hz	75 Hz
Frequencies	{15,12,10,8 4/7}	match	mismatch
	{18.75,15,12.5, 10 5/7}	mismatch	match



- There is no perceptual difference between the conditions, so comfort levels are equal.

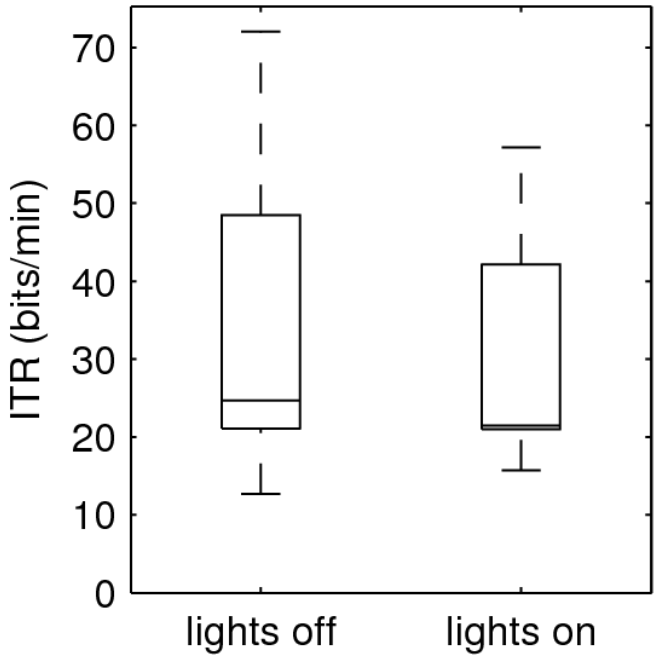
Display device

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



Background illumination

- Frequencies of light in the environment could interfere with the SSVEP response.
- In the dark, the eye becomes more sensitive to luminance changes.
- People generally prefer normal lighting conditions (i.e. lights on).



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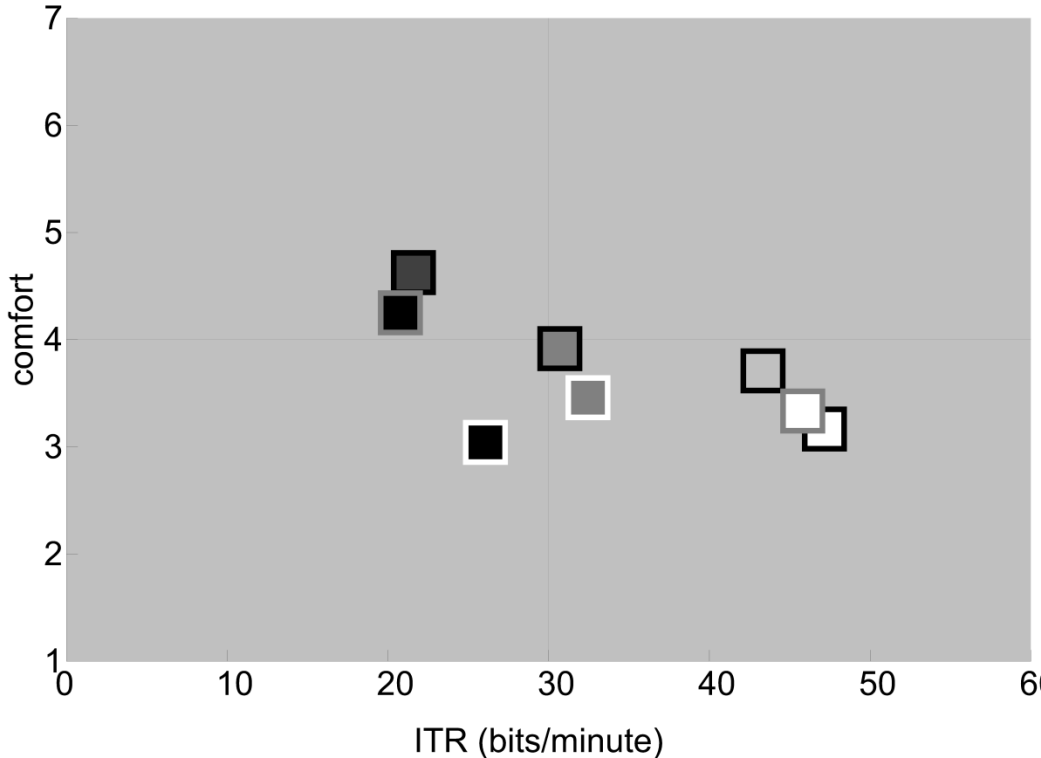
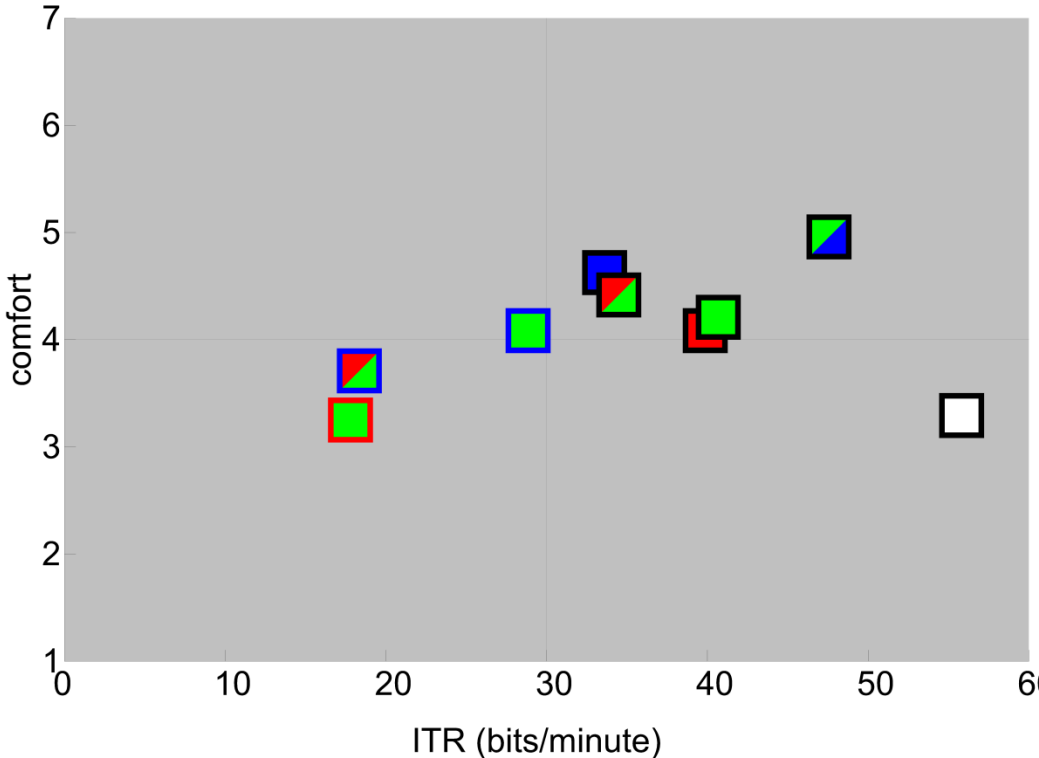
Luminance and contrast

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



Color

- The perceptions of different colors are processed slightly differently in the eyes and brain.
- Instead of varying luminance, hue and saturation can also be alternated.
- Colored stimuli on a black background perform well and are also fairly comfortable.



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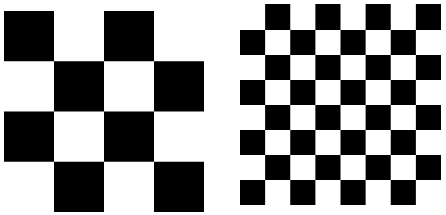
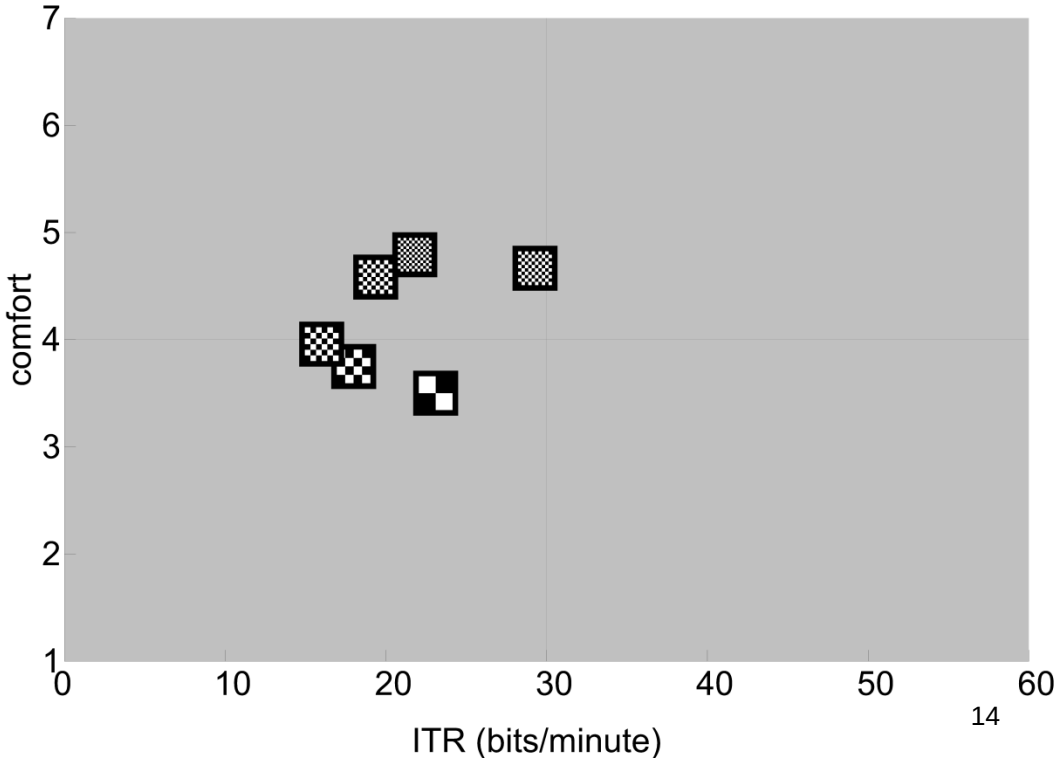
Pattern reversal and spatial frequency

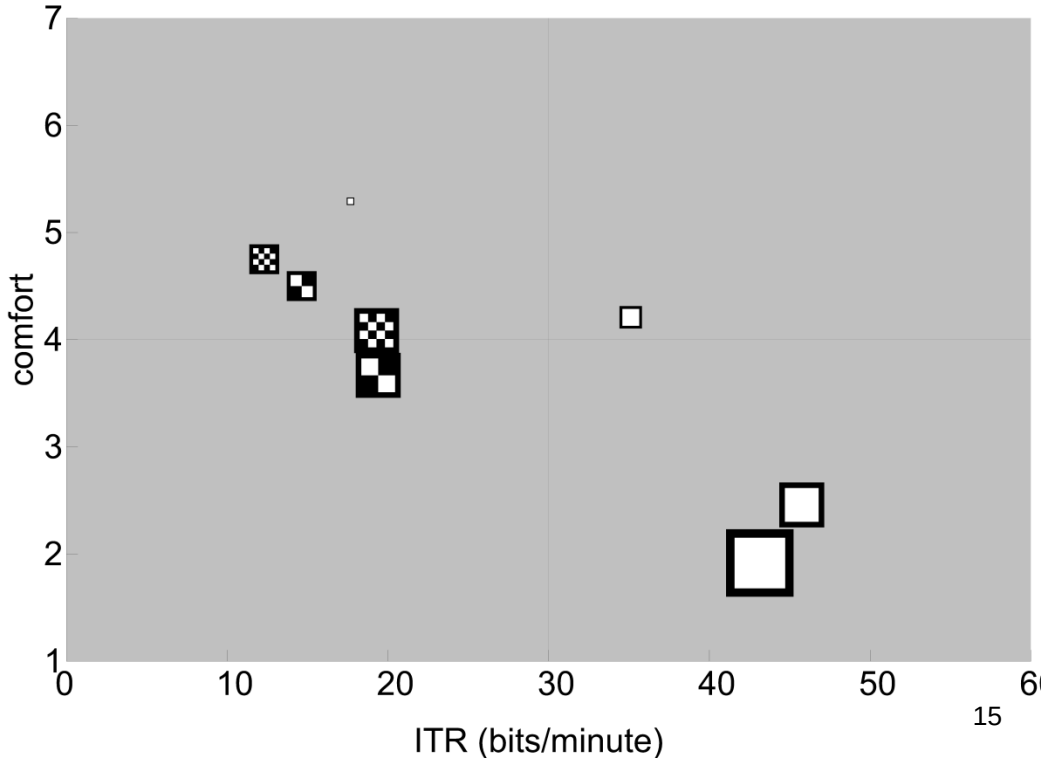
- The SSVEP response is at the alternation rate (or twice the cycle frequency) of the stimulus.
- The spatial frequency of a stimulus defines how many times the pattern is repeated in a certain dimension.
- A higher spatial frequency results in low contrast stimuli and more comfort.





Size

- The stimulus size can increase SSVEP strength regardless of attention.
- This can introduce erroneous BCI classifications.
- There seems to be 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 more noticeable state changes (high contrast, large or low spatial frequency) are less comfortable, but result in better BCI performance.
- Colored stimuli on a black background as well as a 3x3 cm white square are both comfortable and enable good performance.
- Future work:
  - More stimulation properties (e.g. shape, texture, pattern)
  - Interaction between stimulation properties
  - More subjects and applications

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Questions