A visual Brain-Computer Interface for gaze-free communication

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The Locked-in Syndrome

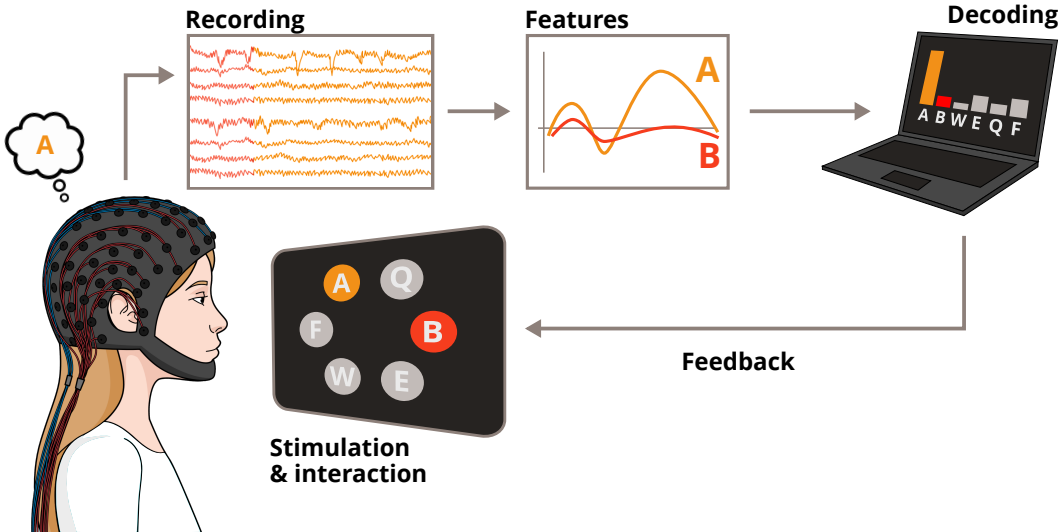
A functioning mind trapped in a paralyzed body

Severe paralysis leads to **Locked-in Syndrome**, due to

- Stroke
- Traumatic brain injury
- Neurodegenerative diseases
- ...

Communication requires **assistive technology**

The Brain-Computer Interface

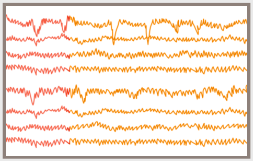


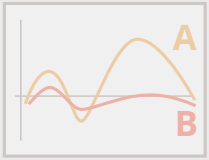
Research question

How can we optimize **BCI** assistive technology design to make it more **inclusive** and **efficient**?

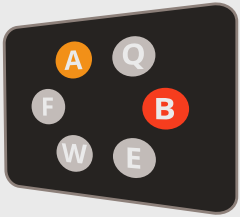
Outline

1. Recording





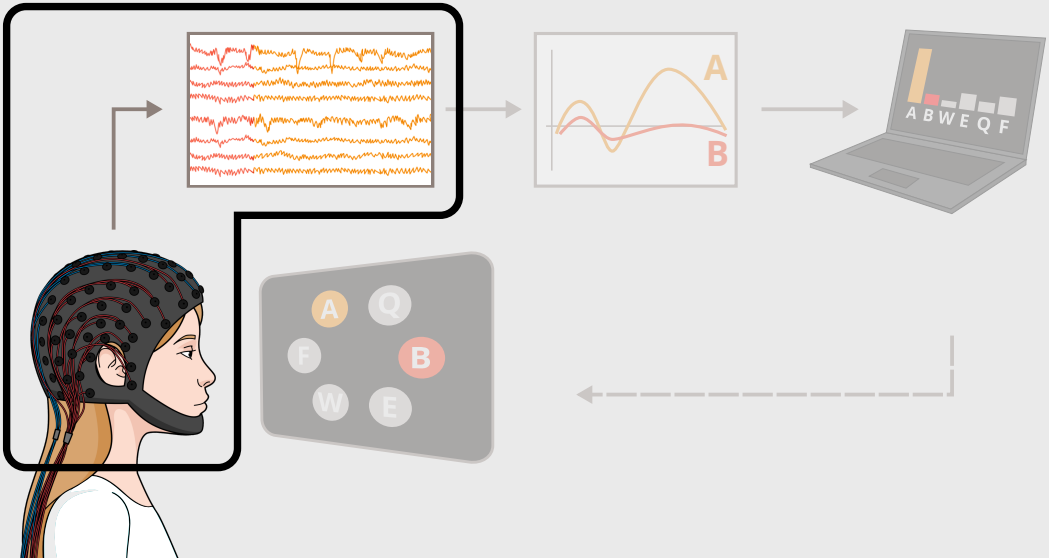
4. ERP decoding
5. gaze-independent decoding



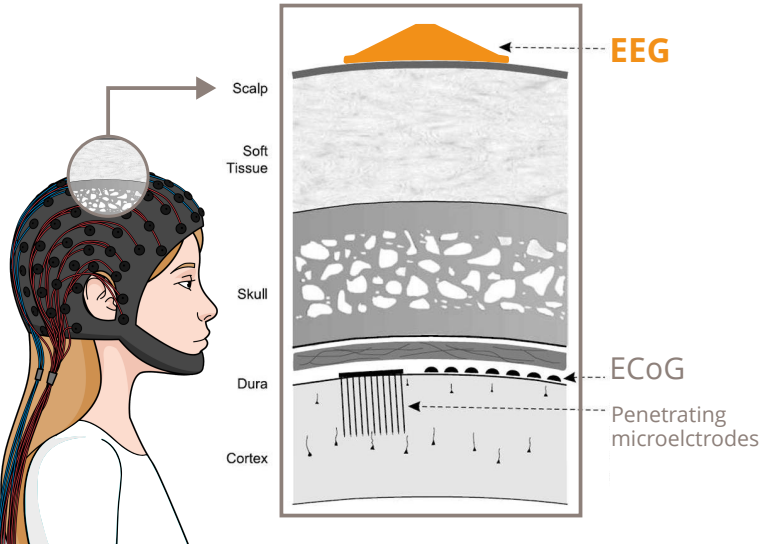
2. Interaction
3. Gaze-independence

6. Evaluation

1. Recording the brain activity



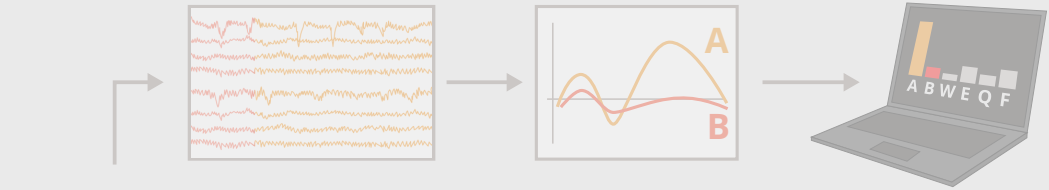
Recording technologies



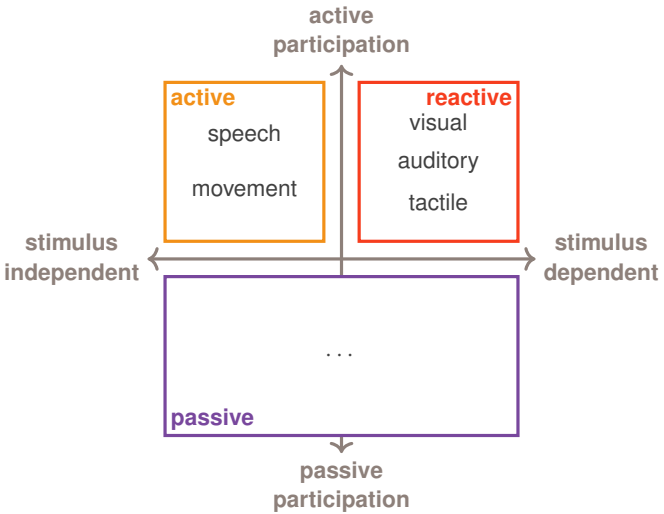
EEG measures the electrical field on the scalp:

- \+ Non-invasive
- \+ Cheap
- – Limited resolution
- – Low signal-to-noise ratio

2. Interaction & stimulation



BCI paradigms



Passive BCIs

- – Less practical

Active BCIs

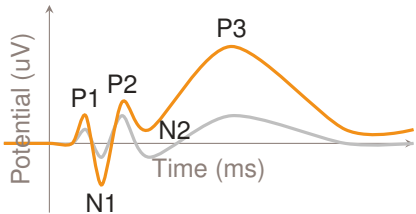
- \+ Intuitive, self-paced
- – High speed requires invasive

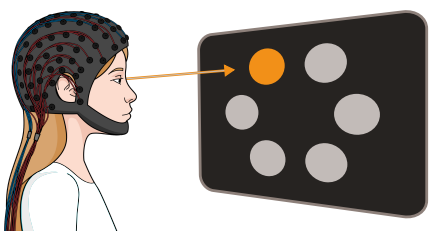
Reactive BCIs decode reactions to attended stimuli

- – Less intuitive
- \+ Fast stimulation
- \+ Suited for EEG

Visual is fastest

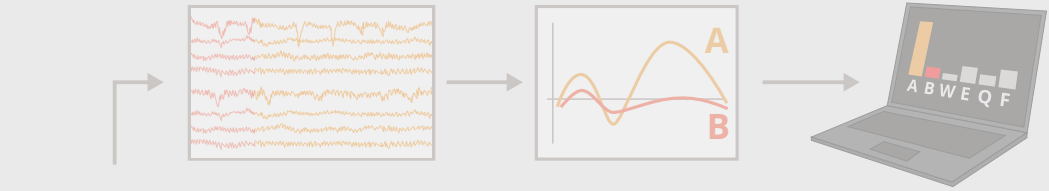
The visual event-related potential paradigm





1. Stimuli flash one by one
2. Flashes evoke ERPs
3. User attends a stimulus
4. ERP components are modulated by attention
5. Decode target based on timing and components

3. Gaze-independence

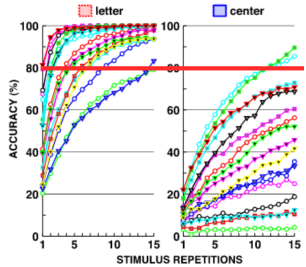


Problem: Eye motor impairment prevents gazing at targets

Visual skills related to disease affect BCI operation Fried-Oken et al., 2020

- Discomfort fixating
- Restricted movement
- Involuntary movements

Decoding relies on **visual ERP** components Treder and Blankertz, 2010



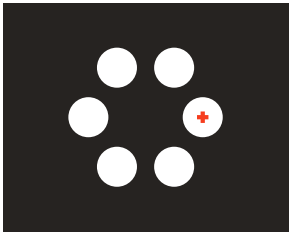
Ron-Angevin et al., 2019

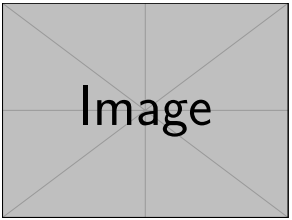
Those who can't use eye tracking need BCIs

but

Visual BCIs perform poorly

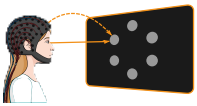
Covert visuospatial attention experiment



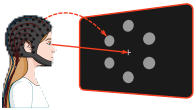


timeline

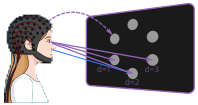
Overt VSA



Covert VSA



Split VSA



CVSA-ERP dataset

- 15 subjects, $\pm$ 11h stimulation
- Hex-o-Spell interface

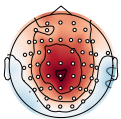
  Treder and Blankertz, 2010
- Discrete gaze-independent conditions

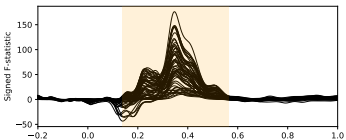
Van Den Kerchove et al., 2024

Evoked ERP components

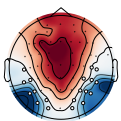
Overt VSA

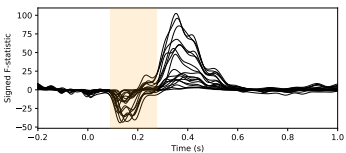
0.140 – 0.564 s

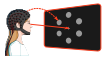




0.088 – 0.274 s

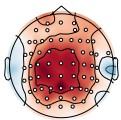


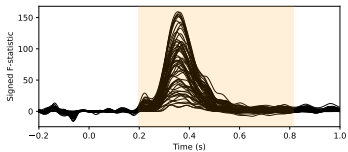


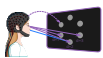


Covert VSA

0.196 – 0.812 s

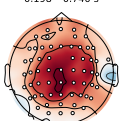


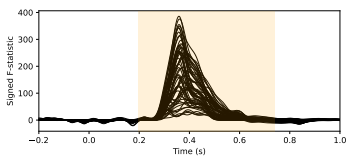




Split VSA

0.198 – 0.740 s





Recap

- Visual, spatial ERP paradigm
- 2 decoders exploiting spatiotemporal structure
- Alignment decoder for gaze independence
- Covert attention study with healthy subjects
- Off-line study with eye-motor impaired patients

Perspectives

- on-line experiments
- component separation
- Improve and find other models that capture multi-component and non-stationary aspect of covert VSA decoding