User–Centric Performance Estimation in a Continuous Online BCI

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Introduction

- How to meaure performance of continuous BCI control?
  → User's control strategy, response time
- How does the user percieve BCI performance?
  → Control response vs. goal completion
- Game–like continuous BCI application (2-class MI)

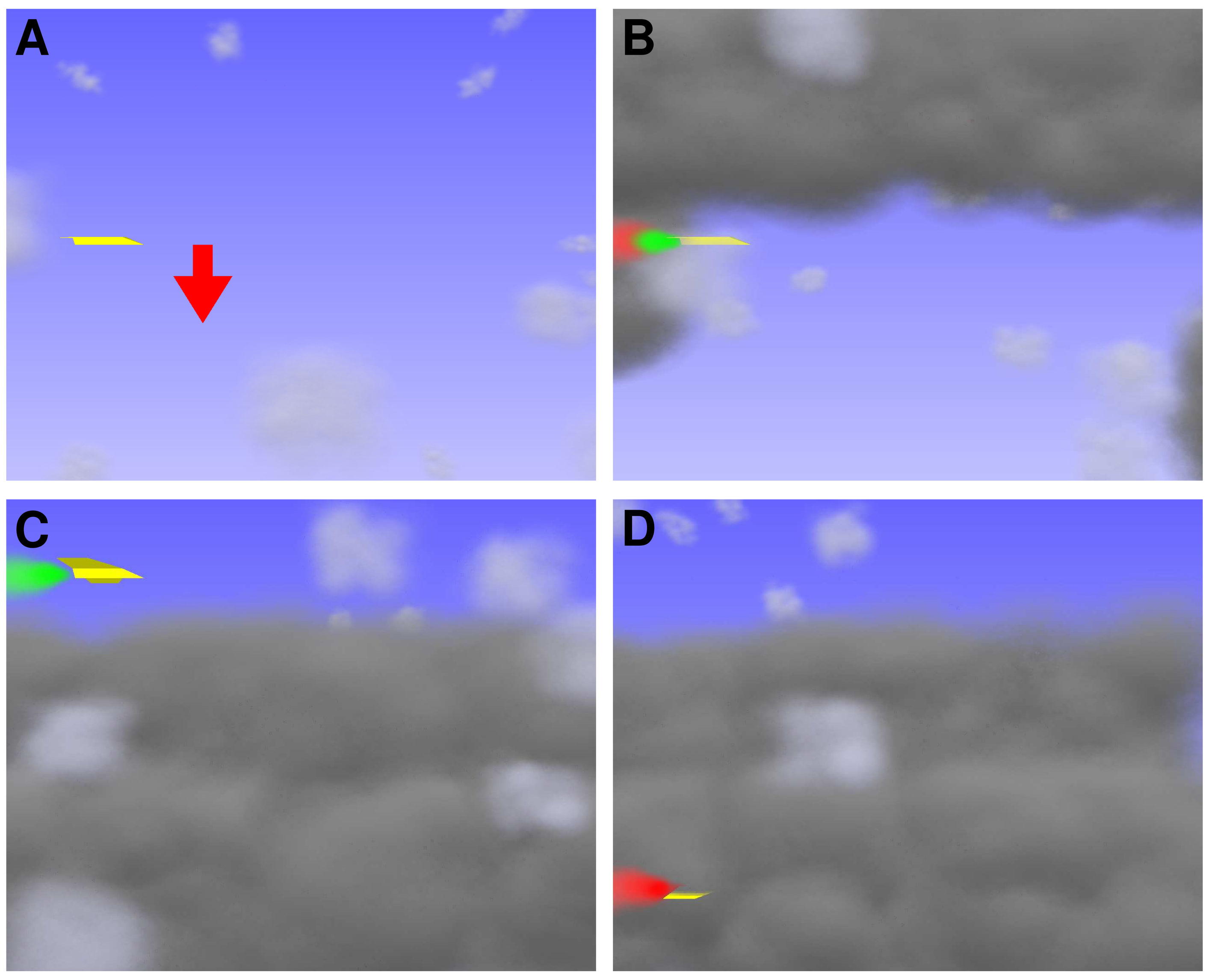

Figure 1: (A) Training. (B) Transition between targets. (C) Positive feedback. (D) Negative feedback.

Methods

Study Design:

- Users steered a virtual airplane along a clear path.
  - Constant horizontal movement, 1-D MI control
  - Feedback: pitch, position, color
- 14 healthy volunteers (age 25.5 ± 4)
- 2 sessions: each 180 trials training, 3x5 minutes feedback
- Standard training procedure, but with game graphics

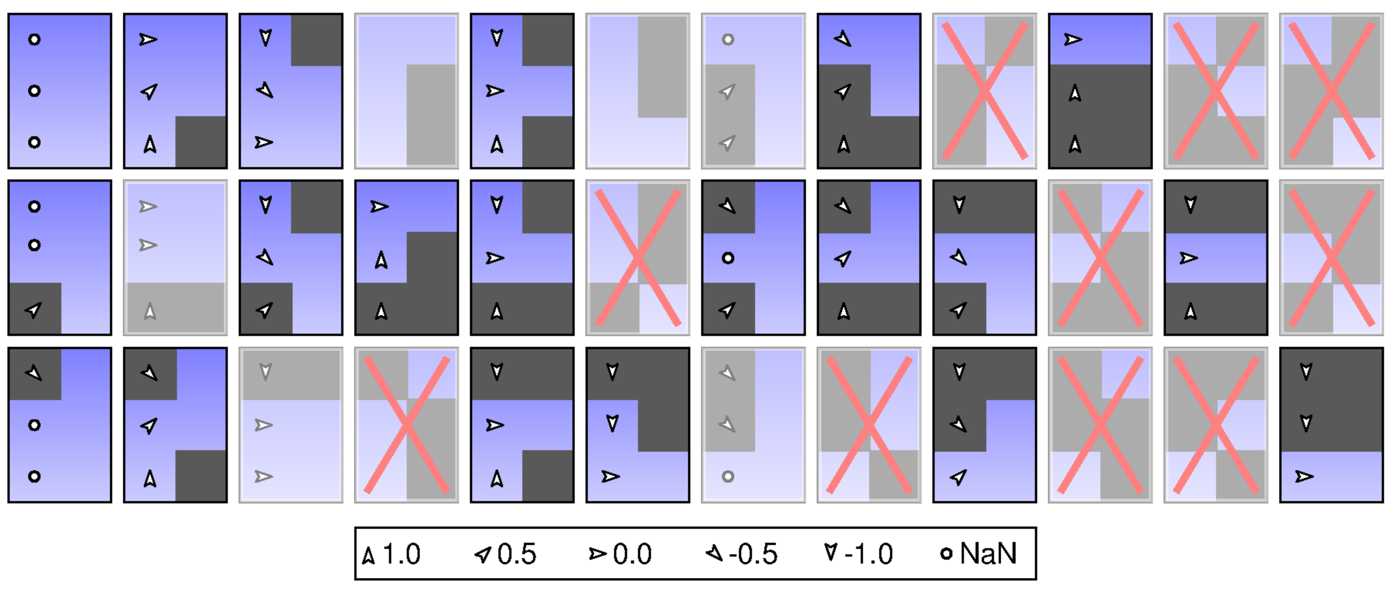

Figure 2: Target Signal. Optimal control choice, dependent on current altitude and visible path. Invalid combinations are grayed out.

Data Acquisition:

- 3 Laplacian EEG derivations (C3, Cz, C4), $fs = 300\,\mathrm{Hz}$
- 3 monopolar EOG channels, $fs = 300\,\mathrm{Hz}$
- 2 bipolar EMG channels (arm, leg), $fs = 2.4\,\mathrm{kHz}$
- Participants rated the controllability of the BCI from -5 to 5.

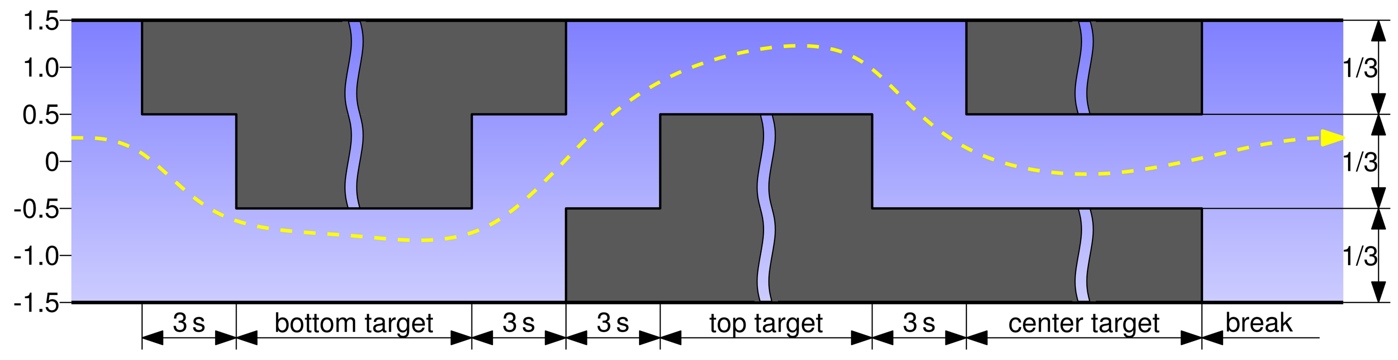

Figure 3: The path is made of distinct targets and transition regions.

Data Processing:

- Regression-based EOG removal
- Post-hoc exclusion of participants based on EMG
- Features: 1 session band power, 1 session autoregressive
- Naive Bayes classifier: class probabilities p_{Hand}, p_{Feet}
- Pitch: $(p_{\mathrm{Hand}} - p_{\mathrm{Feet}}) \cdot 20\,°$, Altitude: $0.5 \int (p_{\mathrm{Hand}} - p_{\mathrm{Feet}}) dt$
- Performance estimation: fraction of time spent on the path.
  - Target hit rate: fraction of time spent on the path.
  - Accuracy: compares target and control signal.
  - Response time: maximum XCF of target and control.

Results

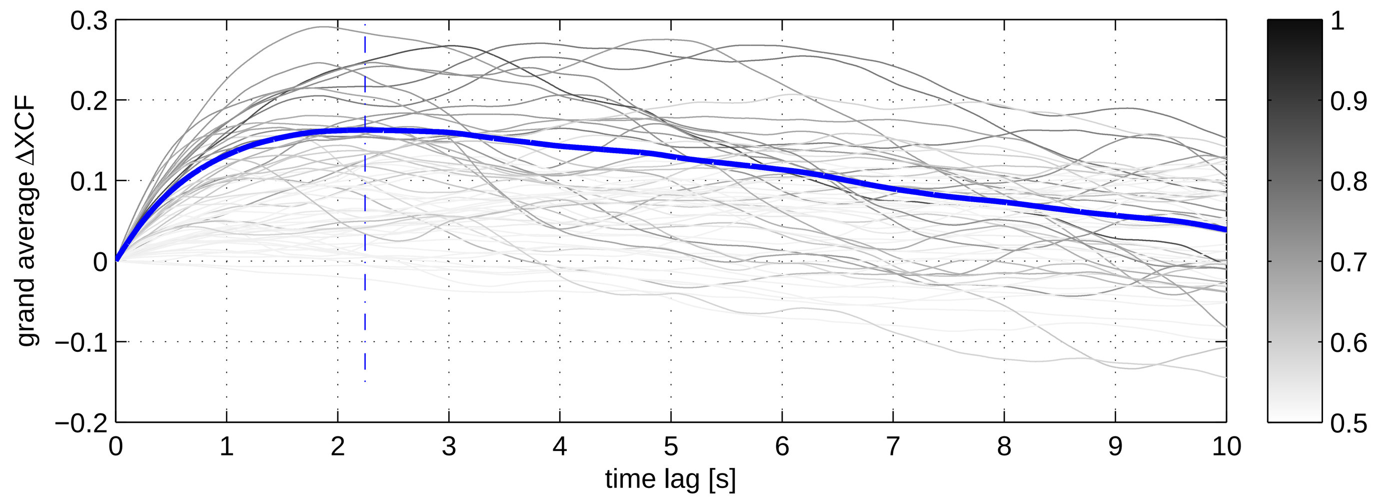

Figure 4: Cross correlation function (XCF) of target and control signal for each individual run. Shading corresponds to classification accuracy. The weighted grand average XCF over all users and runs is plotted in bold blue.

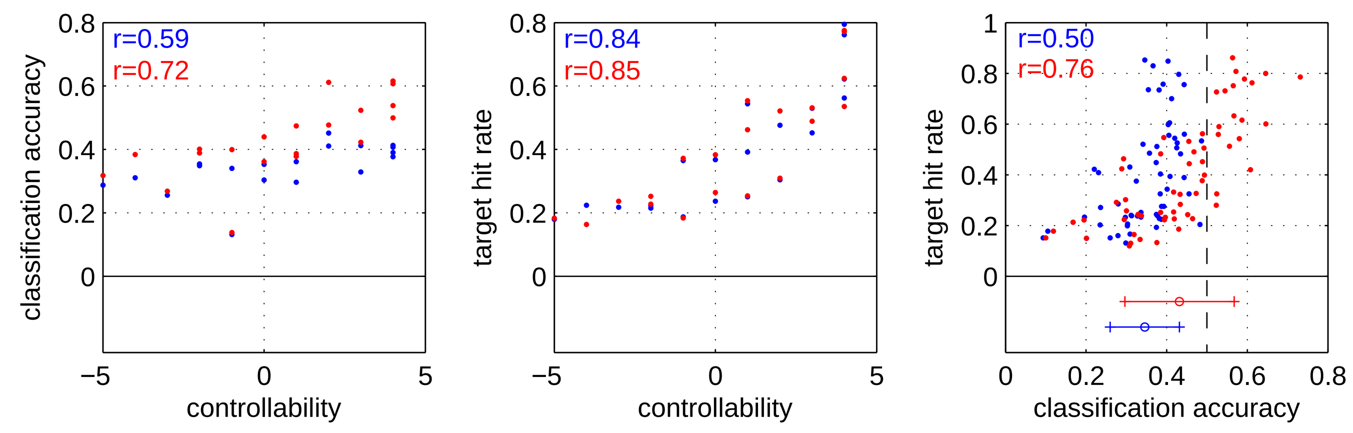

Figure 5: Left: classification accuracy is higher when correcting for response time (red). Center: target hit rate is mostly unaffected by response time. Right: Without correcting for for resnpose time (blue), classification accuracy appears below chance level (dashed line) for all runs.

Conclusion

1. Estimating continuous BCI performance requires knowledge about target, current state and control strategy.
2. Calculating classification accuracy alone is not enough. Also the response time has to be considered.
3. User rating correlates better with target hit rate than with classification accuracy: Success at the task is more important to the user than control response.

References

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