Machine learning-based co-adaptive calibration: A perspective to alleviate BCI illiteracy

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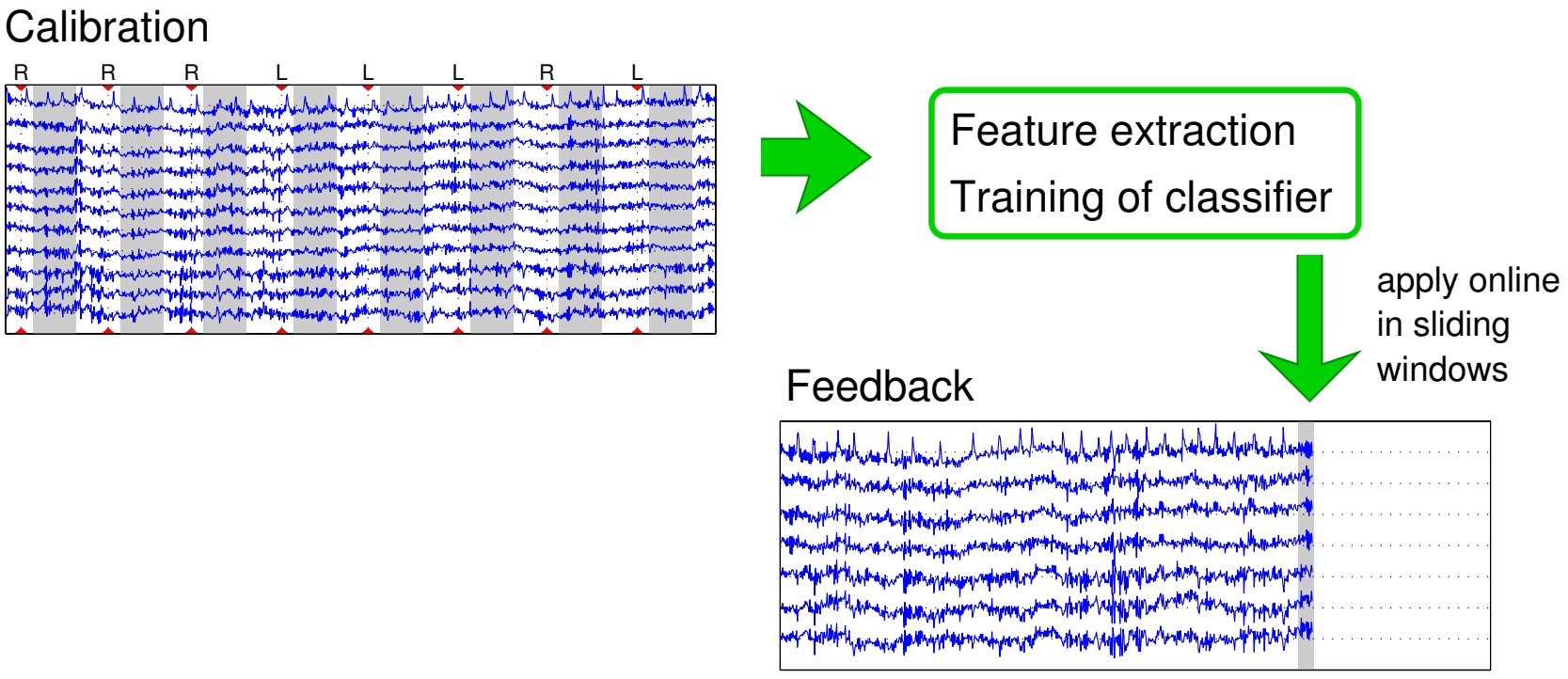
Introduction: Classic BCI paradigm

A prior study (Berlin + Tübingen) performed the screening of 80 inexperienced users in calibration $\Rightarrow$ feedback session (classic machine learning BCI paradigm).



Motivation

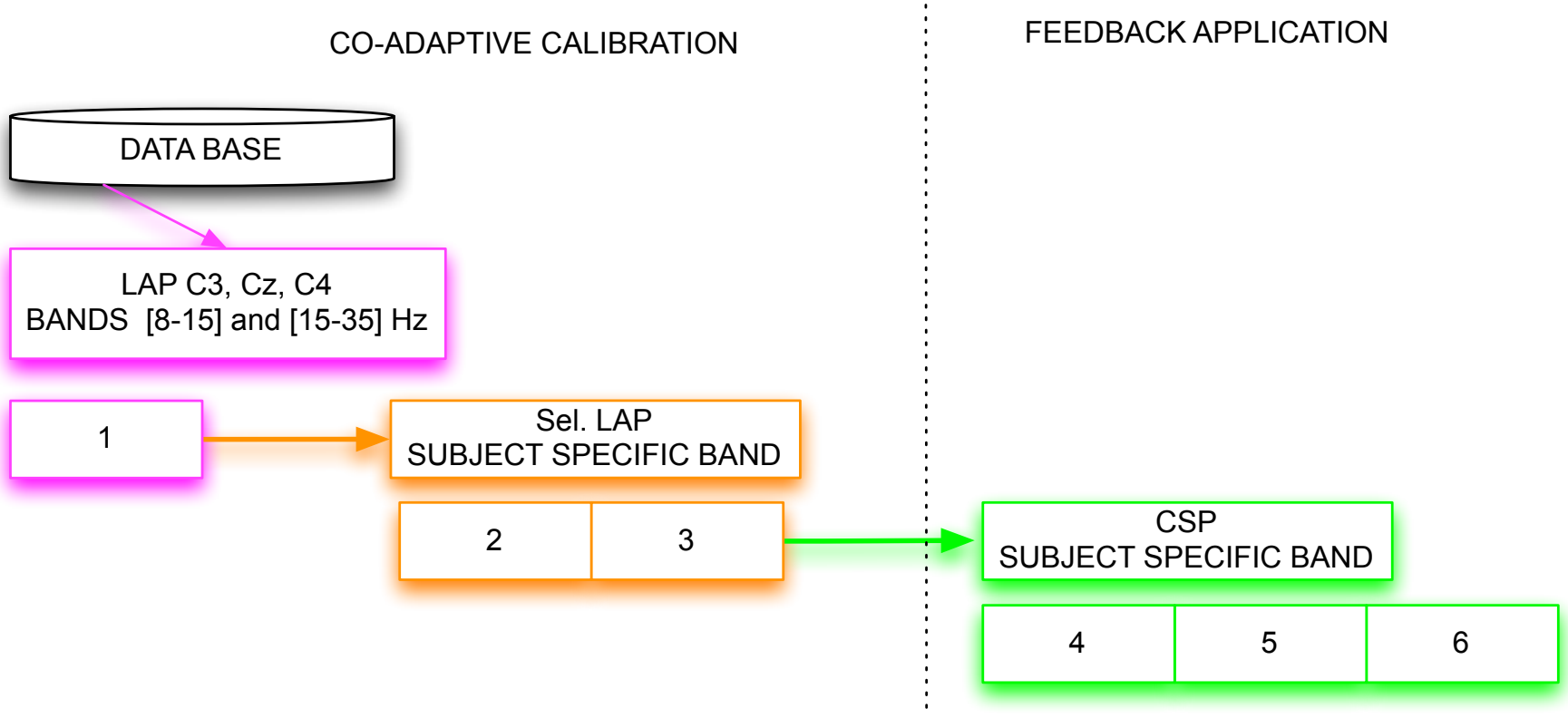
- **The *BCI Illiteracy* Phenomenon**
  20-30% of BCI users do not reach the level needed for control $\sim$ 70% binary classification [Kübler et al. 2004].

- **User categorization**
  Results of a previous study with N=80 naïve users and classical system design with calibration and feedback (Berlin+Tübingen):
  – **Category I**: **Good** calibration and **good** feedback $\sim$ 61%
  – **Category II**: **Good** calibration and **bad** feedback $\sim$ 14%
  – **Category III**: **Bad** calibration, no feedback possible $\sim$ 25%

- **Machine Learning Co-Adaptive Learning** [Vidaurre and Blankertz, 2009]
  System design that helps BCI-users to achieve good feedback.

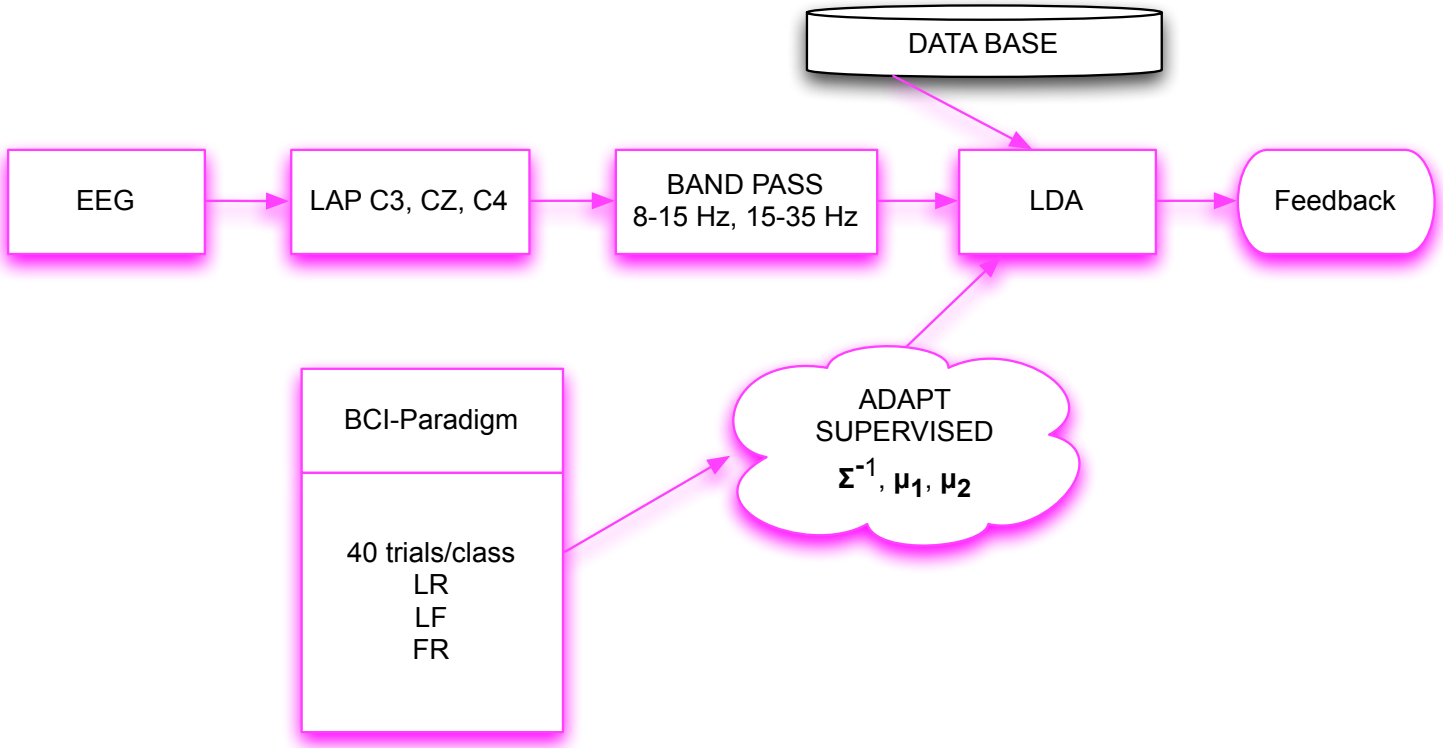
Experimental setup

14 volunteers: 4 novice (no categorization) and 10 **Cat. III**



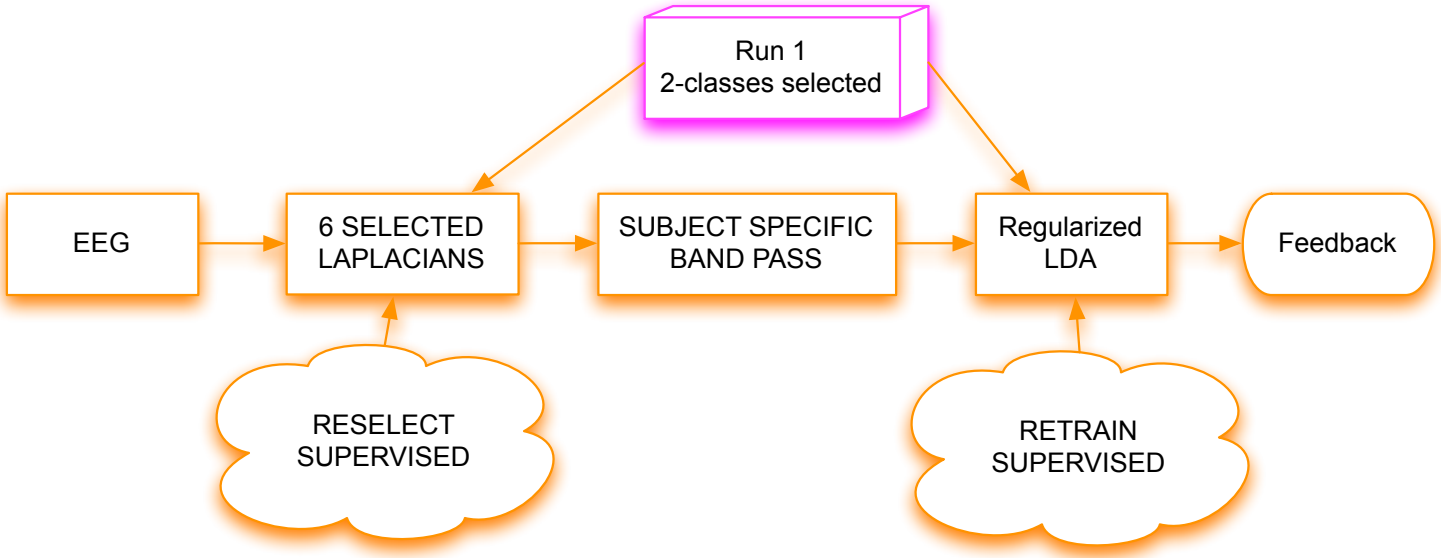
– Feedback immediately [Vidaurre et al. 2006, 2007]
– 3 different levels of adaptation [Vidaurre and Blankertz 2009]
– First run 40 trials/class. Subsequent runs 50 trials/class

Level 1: 1 run



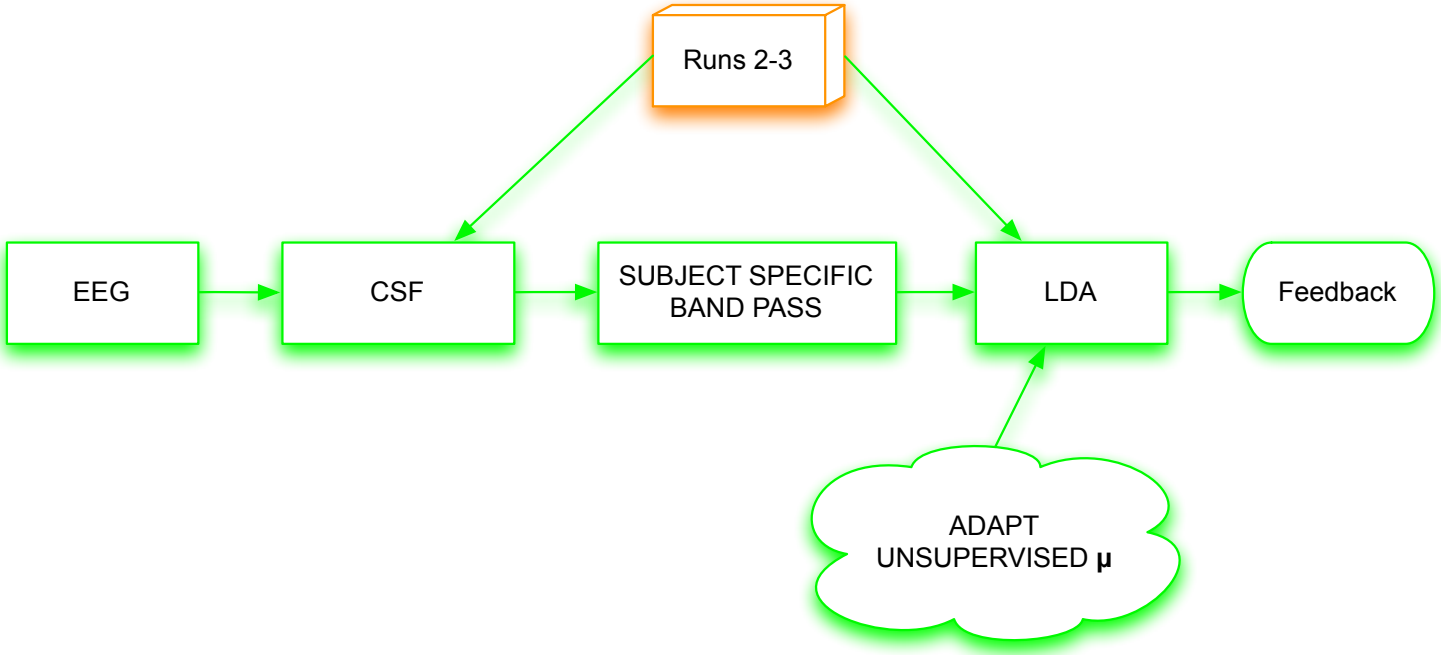
- Pre-trained classifier. Simple methods: fast adaptation
- Lap. C3, Cz y C4, log band-power (8-15 and 15-35 Hz)
- Supervised adaptation: class means and cov. matrix [Vidaurre et al. 2006,2007]
- 3-classes in 3 binary groups (LR, LF, FR), 40 trials/class

Level 2: 2 runs



- Classes, band, Lap. channels from run 1
- 6 sel. laplacians updated after every trial
- Supervised adaptation: retrain classifier [Vidaurre and Blankertz, 2009]

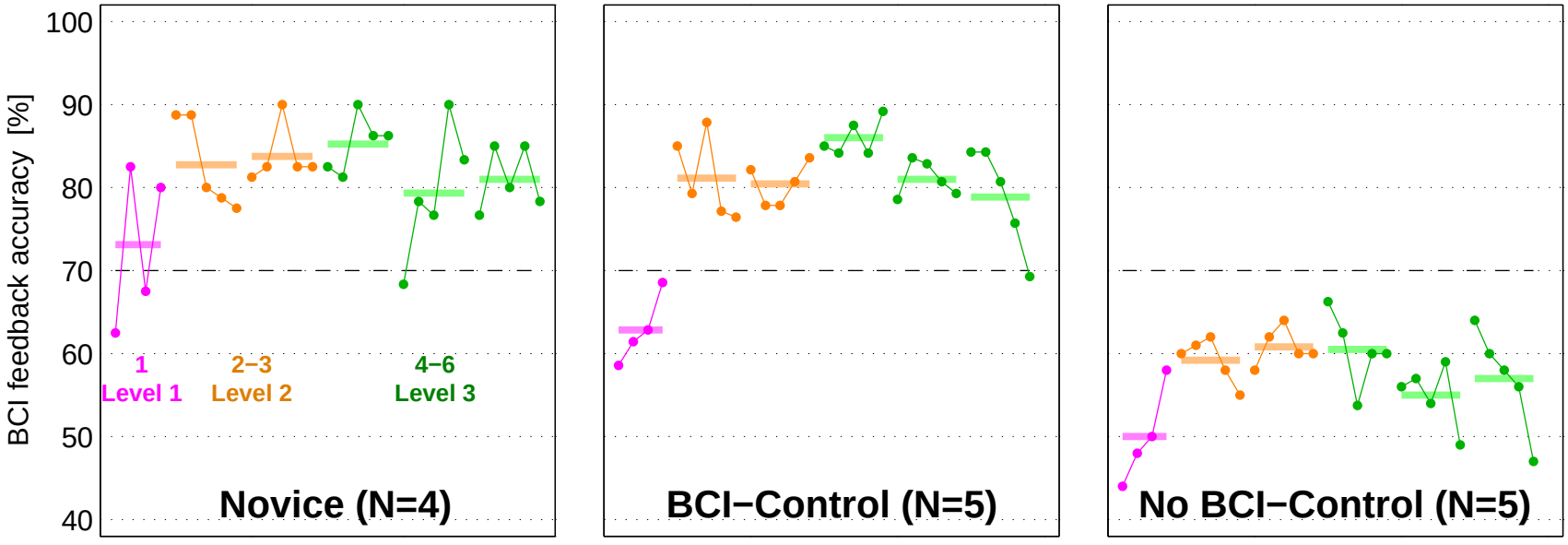
Level 3: 3 runs



- Band and CSF fixed from run 2-3
- Unsupervised adaptation by bias estimation (real performance)

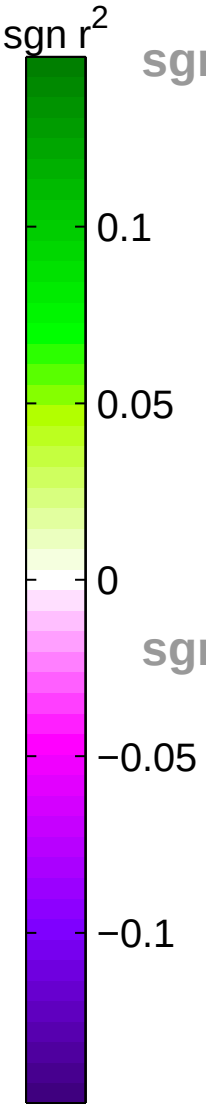
[Vidaurre et al. 2008]

Performance by Category

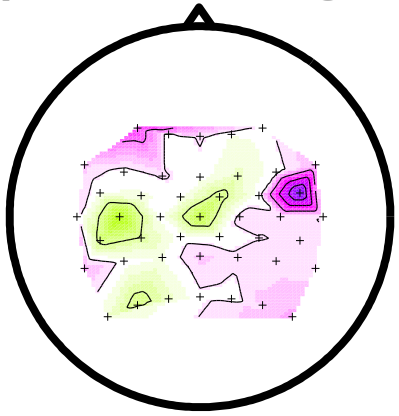


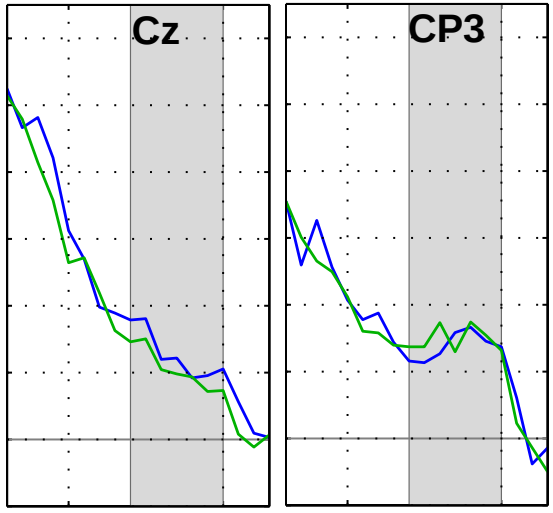
- Performance increase with more complex ML methods (run 2)
- All **4** novice users achieved **good** performance
- **5** Cat. III users overcame BCI-illiteracy
- **2** Cat. III users almost reached the level criterion (∼67%)
- 3 **Cat. III** did not improve over the session

Analysis of one **Cat. III** user

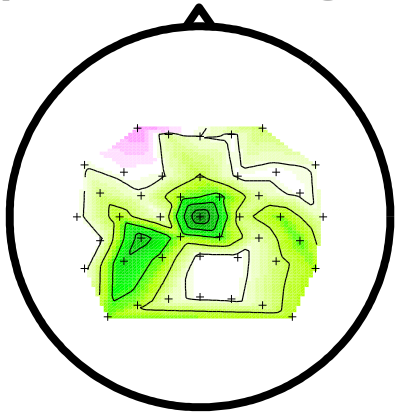


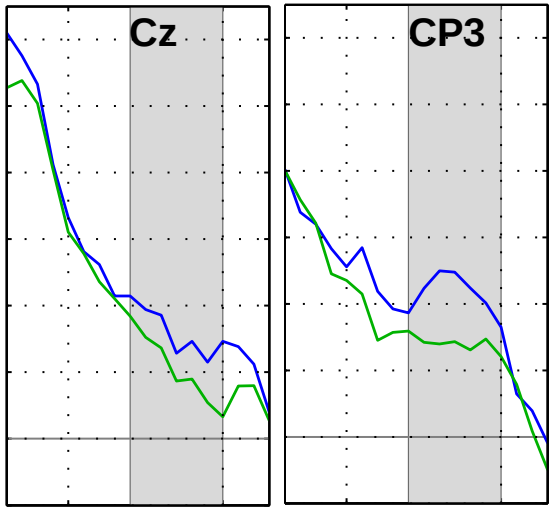
sgn r^2(foot run 1 , right run 1)





sgn r^2(foot run 6 , right run 6)





Discussion

- The simple methods of Level 1 allowed rapid adaptation and good performance for novice users.
- Machine Learning methods (levels 2 and 3) helped 5 Cat. III users to achieve control.
- 2 users more were at the limit of the control threshold.
- Unfortunately, 3 Cat. III participants did not reach control $\Rightarrow$ Operant Conditioning?
- The binary grouping of classes is not consistent (block-effect).

Thanks for your attention

References

① Kübler, Neumann, Wilhelm, Hinterberger, Birbaumer, Predictability of Brain-Computer Communication, J. Psychophysiol., 2004

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③ Vidaurre, Schlögl, Blankertz, Kawanabe, Müller, Unsupervised adaptation of the LDA classifier for Brain-Computer Interfaces Proc. 4th Int BCI Workshop and Training Course 2008, Verlag der TUGraz, 2008

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⑤ Vidaurre, Schlögl, Cabeza, Scherer, Pfurtscheller, A fully on-line adaptive BCI, IEEE tbme, 2006