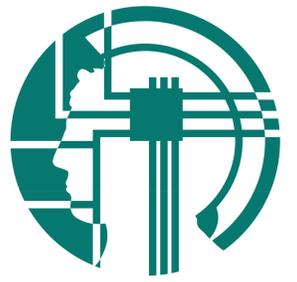




# Informative Brain Regions During Motor Imagery: Evidence from Four Normal and One ALS Subject

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## Introduction

### Background:

- Motor imagery is the most frequently used paradigm in non-invasive Brain-Computer Interfaces (BCIs) [1], even though amyotrophic lateral sclerosis (ALS) is a disease of the motor system.
- While brain regions involved in motor imagery are well known in normal subjects, very little is known on brain activation patterns during motor imagery of subjects diagnosed with ALS.

### Goal:

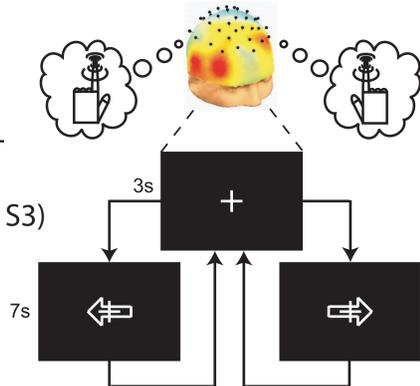
To identify brain regions providing information on the intention of a subject diagnosed with ALS in a non-invasive BCI based on motor imagery.

### Main Result:

In one subject in an advanced state of ALS only left premotor cortex provided information on the subject's intention.

## Experimental Setup

- Motor imagery-paradigm of the left and right hand.
- 128-channel EEG @ 500 Hz, CAV
- One subject (S1) with ALS, artificially ventilated, residual control of the right hand.
- Four normal subjects with previous (S2 & S3) and no prior BCI experience (S4 & S5)
- 90 trials without feedback (offline)
- 90 (S1) / 180 (S2-S5) trials with feedback (online)



## Data Evaluation

### Offline Analysis:

1. Perform source localization in a four-shell spherical head model using linearly constrained minimum variance spatial filtering (LCMV) [2].
2. For each source and trial, extract bandpower in frequency bands of 2 Hz width from 1 to 41 Hz using 6th-order Butterworth filters.
4. Compute classification accuracy for each single source using l1-regularized logistic regression [3] with 9-fold cross validation and heuristically chosen regularization parameter.
5. Plot spatial distribution of classification accuracy.

### Online Analysis:

1. Use beamforming as described in [4] to estimate current density in left/right primary motor cortex (M1).
2. Extract bandpower of estimated current density in left/right M1 in frequency bands of 2 Hz width from 1 to 41 Hz using 6th-order Butterworth filters.
3. Train a l1-regularized logistic regression classifier on data recorded for offline analysis.
4. Provide feedback (falling ball) on classifier output during online performance.

## Discussion

### Summary:

- In normal subjects premotor cortex (PM), primary motor cortex (M1), and sensorimotor cortex (SMC) bilaterally provided information.
- In the ALS-subject only left premotor cortex provided information.

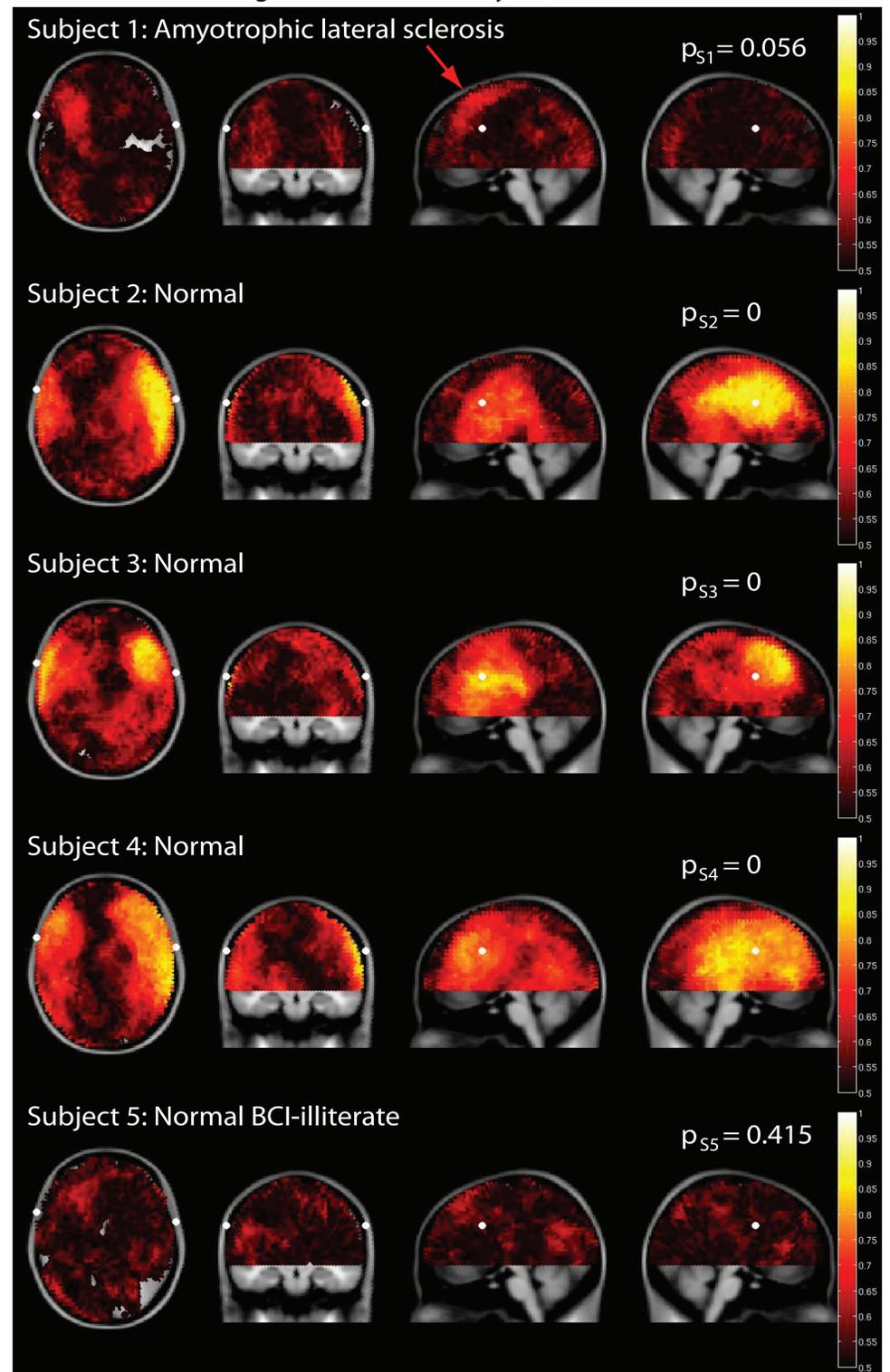
### Conclusions:

- Primary motor as well as sensorimotor cortex might not provide information suitable for motor imagery based BCIs in late stages of ALS.
- Informative activity in left premotor cortex of the ALS-subject could be related to residual motor control of the right hand, and hence might not persist throughout disease progression.
- Motor imagery might not be a suitable paradigm for subjects in late stages of ALS, but more evidence is required.

## Experimental Results

SubjectID	Status	Classification Accuracy		Informative Brain Regions		
		Online	Offline	PM	M1	SMC
1	ALS	50.6%	72.2%	left hem.	X	X
2	Normal	92.2%	91.1%	right hem.	bilateral	bilateral
3	Normal	71.7%	90.0%	bilateral	bilateral	left hem.
4	Normal	68.4%	90.0%	bilateral	bilateral	bilateral
5	Normal	50.0%	68.9%	X	X	X

### Informative Brain Regions in Offline Analysis:



## References

1. Mason S.G., A. Bashashati, M. Fatourehchi, K.F. Navarro, and G.E. Birch. "A comprehensive survey of brain interface technology designs". *Annals of Biomedical Engineering*, vol. 35(2), pp. 137-169, 2007.
2. Van Veen, B.D., W. van Drongelen, M. Yuchtman, and A. Suzuki. "Localization of brain electrical activity via linearly constrained minimum variance spatial filtering", *IEEE Transactions on Biomedical Engineering*, vol. 44(9), pp. 867-880, 1997.
3. Koh, K. S.-J. Kim, and S. Boyd. "An Interior Point Method for Large-Scale l1-Regularized Logistic Regression", *Journal of Machine Learning Research*, vol 8, pp. 1519-1555, 2007.
4. Grosse-Wentrup, M., C. Liefhold, K. Gramann, and M. Buss. "Beamforming in Non-invasive Brain-Computer-Interfaces", *IEEE Transactions on Biomedical Engineering*, vol. 56(4), pp. 1209-1219, 2009.