Investigation of Graded Event-Related Desynchronization of the Sensorimotor Rhythm for BCI Applications

Chase Haddix and Sridhar Sunderam†
F. Joseph Halcomb III M.D. Department of Biomedical Engineering,
University of Kentucky, Lexington, KY

University of Kentucky Neural Systems Lab

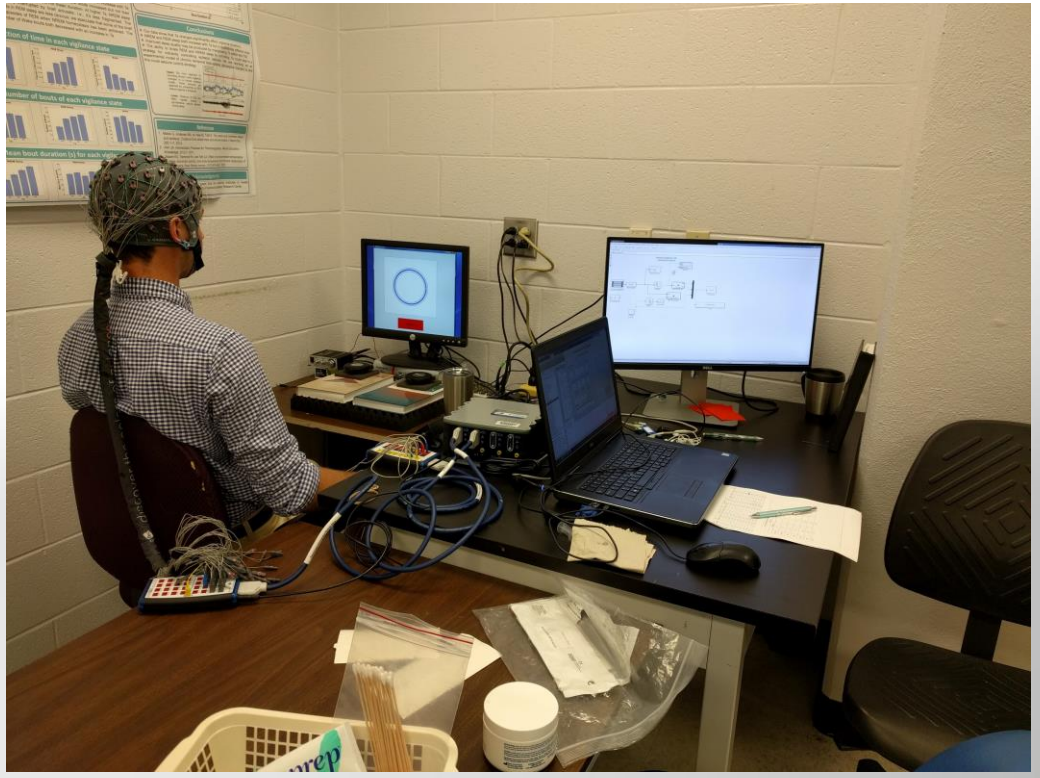
College of Engineering
F. Joseph Halcomb III, M.D.
Department of Biomedical Engineering

Objective: Model Graded SMR for Fine Control

BCI systems have not reached their full potential in the rehabilitative sector. Often, BCIs are modeled on binary tasks, e.g., movement versus rest.

Gradations in effort or fine control are not explicitly modelled but instead left to the controller to handle in a goal-directed task.

Using non-invasive EEG, we propose to classify the effort in a specific motor task to increase the available degrees of freedom of BCI command signals and enable finer control.



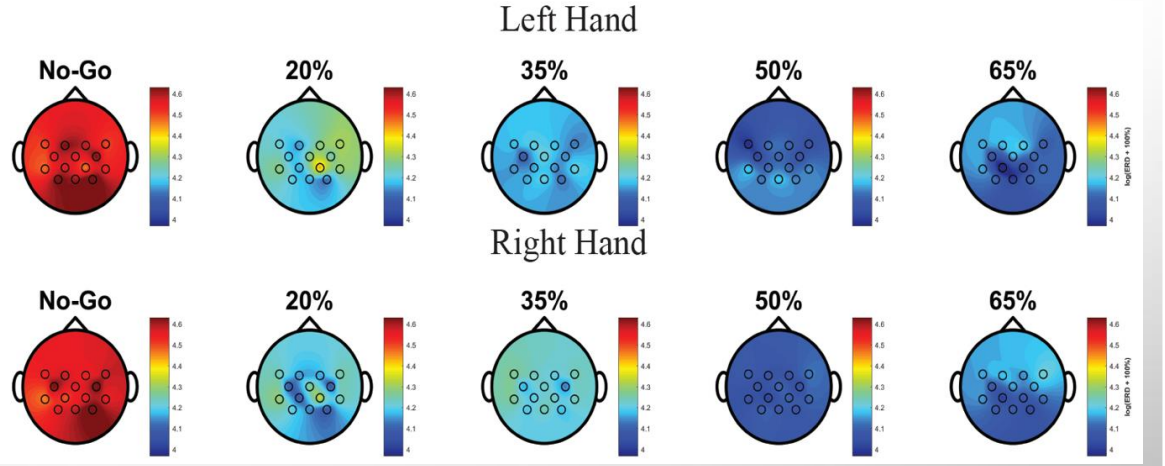
Study 1: Modeling SMR Gradation in Healthy Subjects

1. EEG + EMG + force, n = 14
   - 4 effort + 1 no-go target, both hands
2. 1-sec ERD averages during task
3. Offline classification

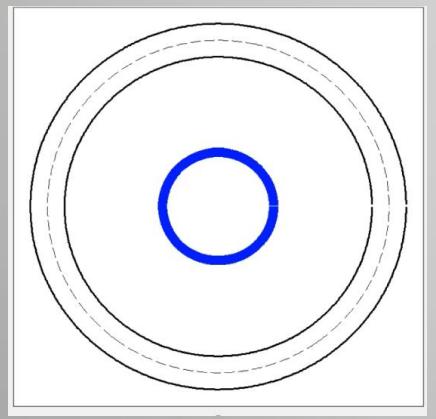
$$X_{i,j} = \frac{1}{N}\sum_{i=1}^{N} y_{i,j}^2$$

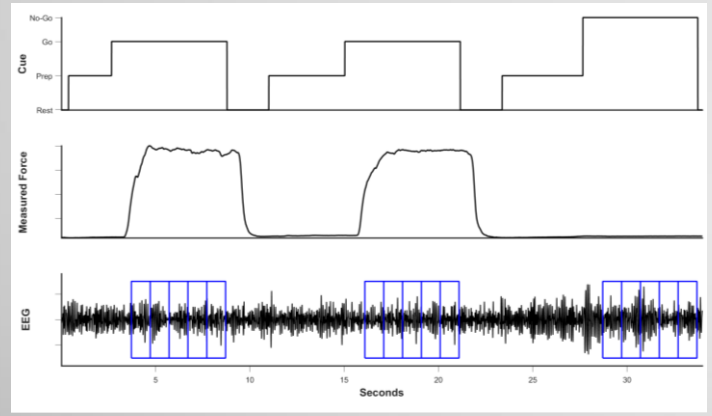
$$R_{i,j} = \frac{1}{K+1}\sum_{m=1}^{K} X_{i,j}$$

$$ERD_{i,j}(\%) = \left(\frac{X_{i,j} - R_{i,j}}{R_{i,j}}\right) \times 100\ (\%)$$



Haddix et al. 2021, *in review*





LDA

Dominant Hand

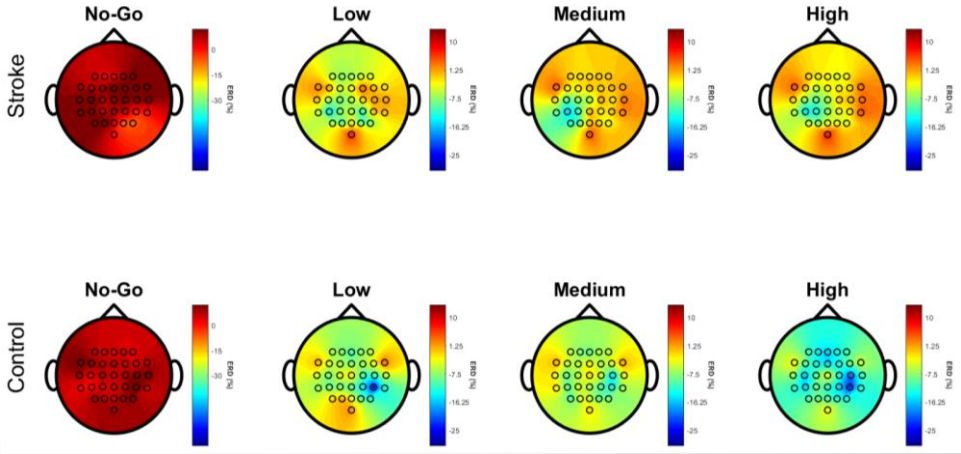
True Class \ Predicted Class	No-Go	20%	35%	50%	65%
No-Go	54%	14%	14%	10%	9%
20%	8%	42%	22%	16%	12%
35%	9%	16%	47%	16%	11%
50%	3%	16%	13%	61%	6%
65%	4%	11%	15%	7%	63%

Non-Dominant Hand

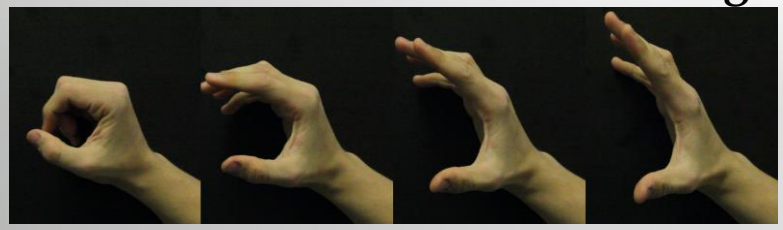
True Class \ Predicted Class	No-Go	20%	35%	50%	65%
No-Go	49%	15%	11%	13%	11%
20%	12%	42%	21%	16%	9%
35%	7%	14%	60%	11%	8%
50%	7%	15%	13%	55%	9%
65%	4%	10%	8%	10%	67%

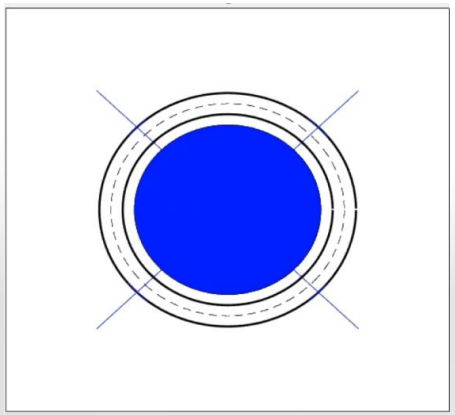
Study 2: Modeling SMR Gradation in Stroke Subjects

1. EEG + EMG + motion capture glove, n = 7 (3 stroke, 4 control)
   - 3 effort + 1 no-go target, both hands
2. 1-sec ERD averages during movement
3. Offline classification with QDA

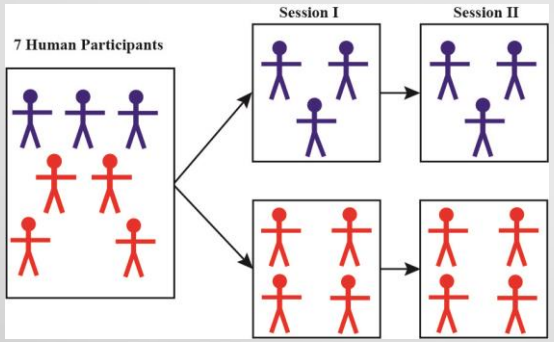


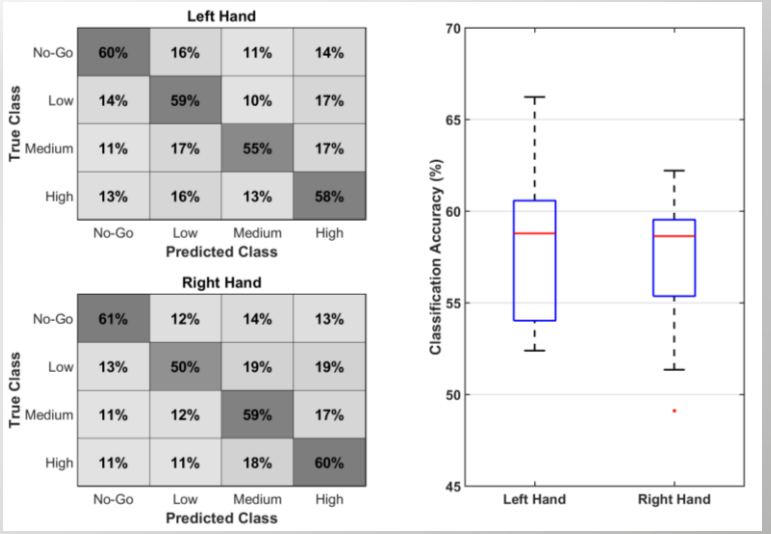
No-Go Low Medium High





ID	Age	Gender	Stroke	Time Since Stroke (m)	FMA
1	29	M	H	150	33
2	69	M	I	110	23
3	67	M	I/H	93	18
4	61	M	-	-	-
5	64	M	-	-	-
6	68	M	-	-	-
7	33	M	-	-	-





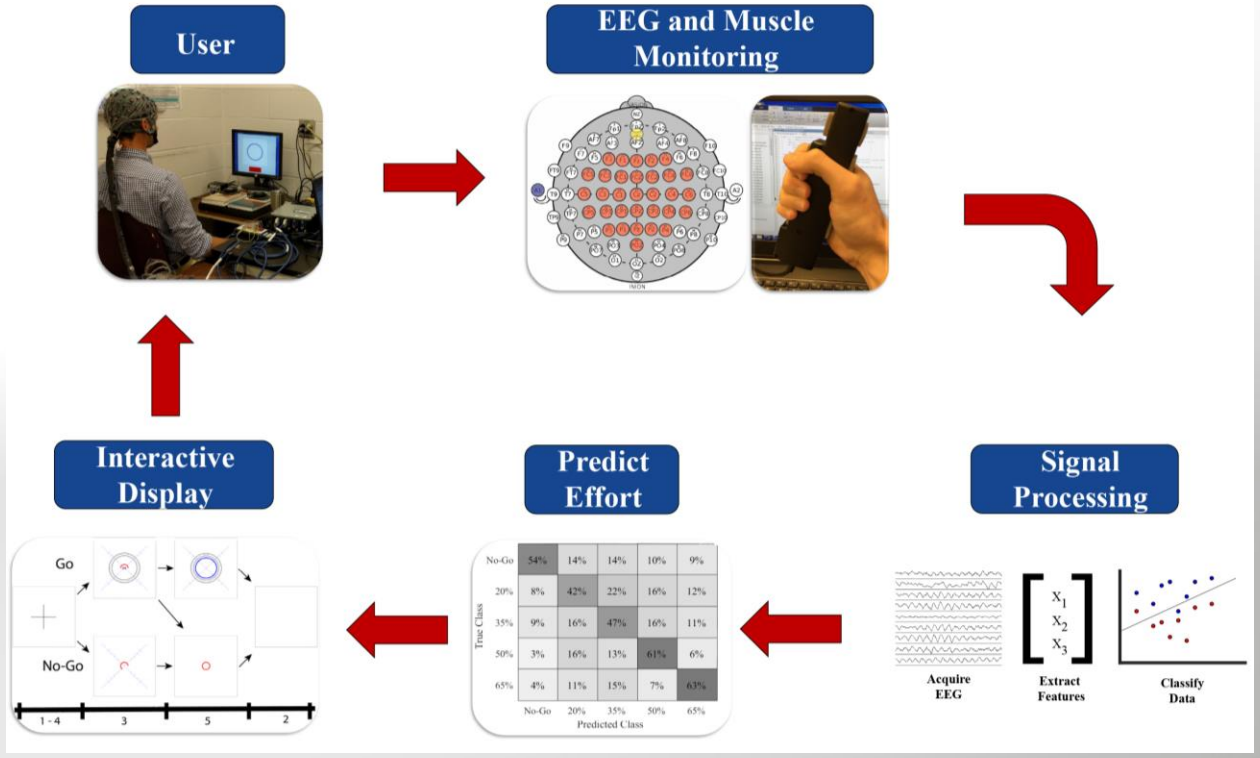
Conclusions and Future Work

Our work suggests:

- SMR suppression is non-linearly related to the degree of effort in the task
- Simple classifiers can predict the degree of effort in healthy and stroke users

Ongoing work:

- Predict effort from the EEG during motor planning period
- Deliver EEG-based real-time feedback on graded effort



Acknowledgements

This work was supported by National Science Foundation grants 1539068 and 1849213 and the Halcomb Fellowship in Medicine and Engineering

Lumy Sawaki, Elizabeth Salmon Powell
University of Kentucky Dept of Physical Medicine and Rehabilitation
Madison Bates
University of Kentucky Dept of Biomedical Engineering