Predictive Modeling of Graded Sensorimotor Neural Signals

Chase Haddix

University of Kentucky, Department of Biomedical Engineering

October 19, 2018

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What is a Brain-Machine Interface ?

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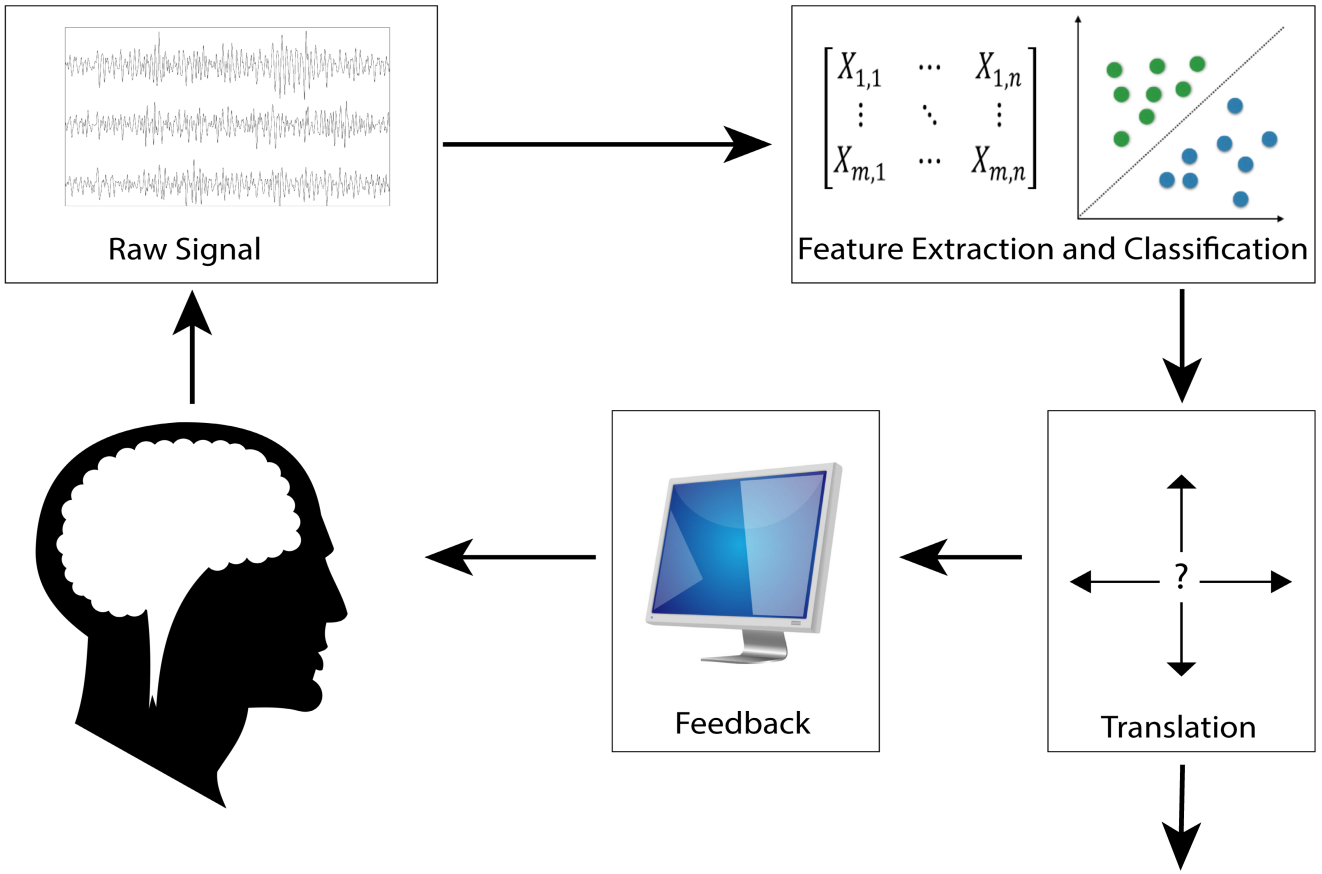
What is a Brain-Machine Interface?

System that translates brain signals into commands for a device



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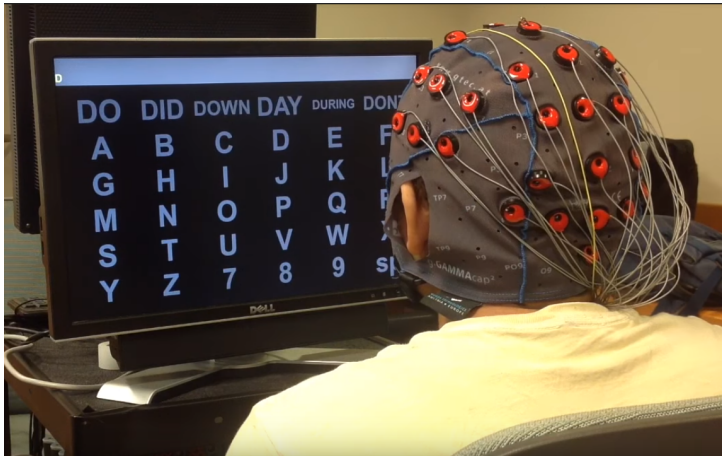
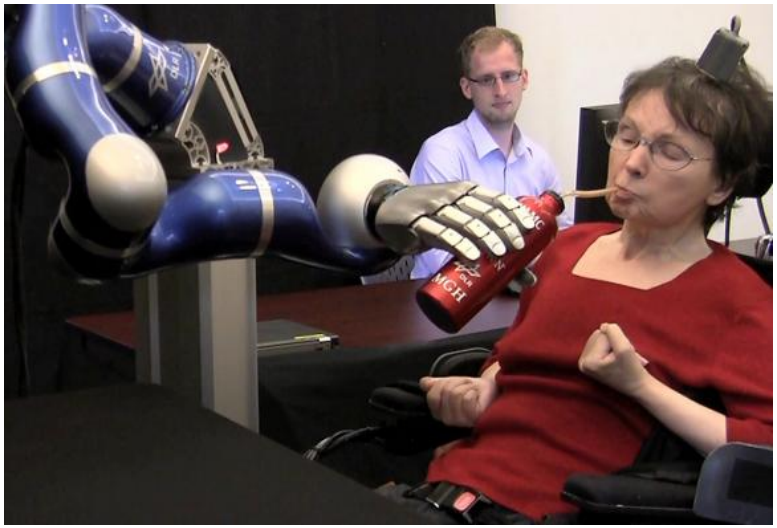
University of Pittsburgh, RNEL



UCLA, Medical Imaging Informatics

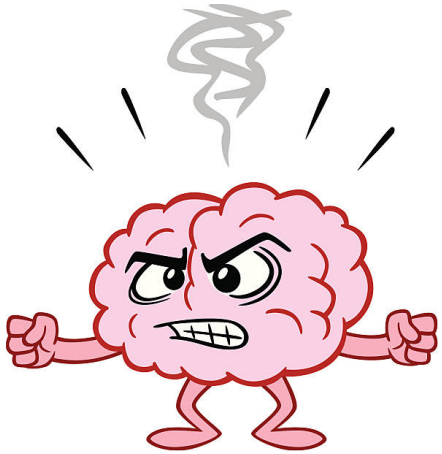


Brown University, Carney Institute for Brain Science

g.BCIsys, g.tec Medical Engineering

Limitations of Current Technology

- Unnatural Control



- Limited Control

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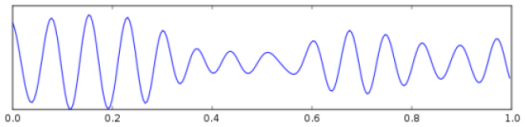
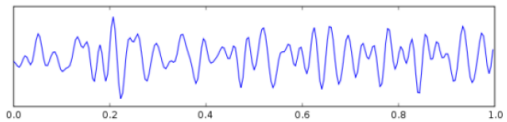
Sensorimotor Rhythm (SMR)

Type	Frequency range (Hz)	Signal Shape	Properties	Mental Activity
Mu (μ)	8 - 13		Sensorimotor cortex	Suppression indicates that motor neurons are working
Beta (β)	12 - 30		sensorimotor cortex, between C3 and C4 , symmetrical distribution, most evident frontally; low amplitude waves	Alert, thinking and active concentration.

Ramadan et al. 2016

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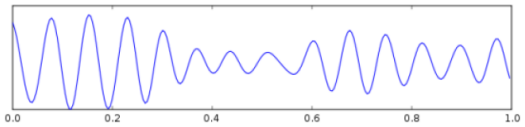
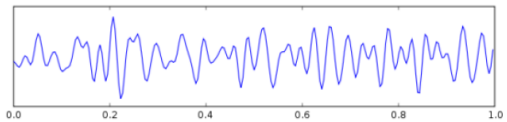
Mu (μ)	8 - 13		Sensorimotor cortex	Suppression indicates that motor neurons are working
Beta (β)	12 - 30		sensorimotor cortex, between C3 and C4 , symmetrical distribution, most evident frontally; low amplitude waves	Alert, thinking and active concentration.

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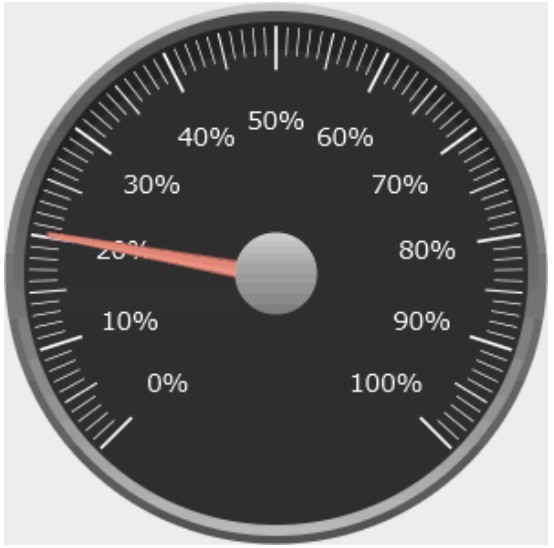
Control Signals : Graded SMR modulation

- Hand grip force activity
- Find difference between different levels of effort
- Effort = % of maximum exerted force
  - 4 different levels



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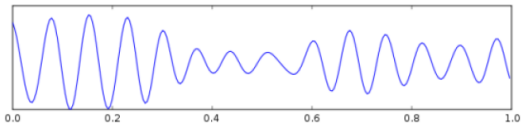
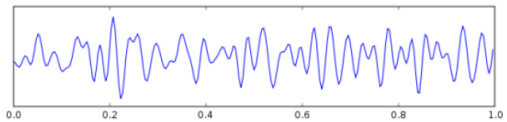
Mu (μ)	8 - 13		Sensorimotor cortex	Suppression indicates that motor neurons are working
Beta (β)	12 - 30		sensorimotor cortex, between C3 and C4 , symmetrical distribution, most evident frontally; low amplitude waves	Alert, thinking and active concentration.

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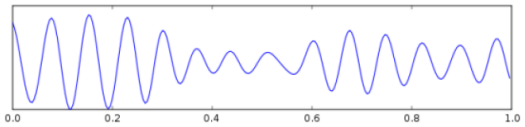
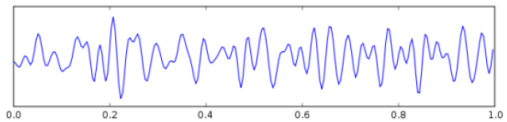
Mu (μ)	8 - 13		Sensorimotor cortex	Suppression indicates that motor neurons are working
Beta (β)	12 - 30		sensorimotor cortex, between C3 and C4 , symmetrical distribution, most evident frontally; low amplitude waves	Alert, thinking and active concentration.

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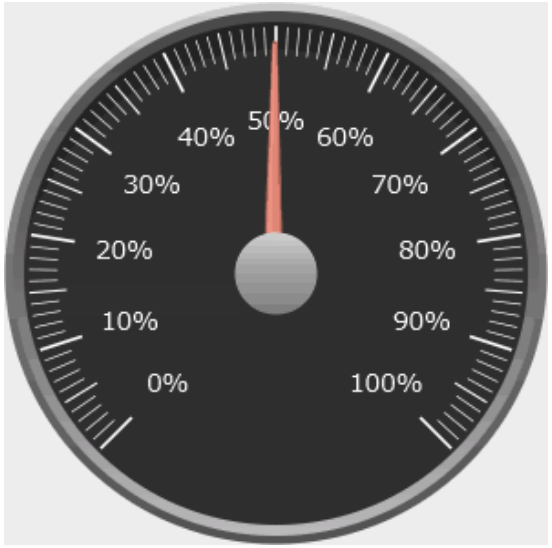

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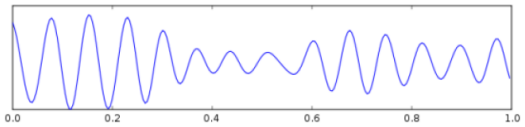
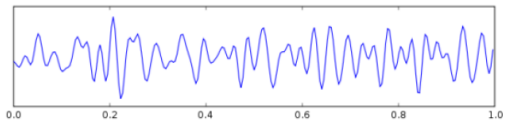
Mu (μ)	8 - 13		Sensorimotor cortex	Suppression indicates that motor neurons are working
Beta (β)	12 - 30		sensorimotor cortex, between C3 and C4 , symmetrical distribution, most evident frontally; low amplitude waves	Alert, thinking and active concentration.

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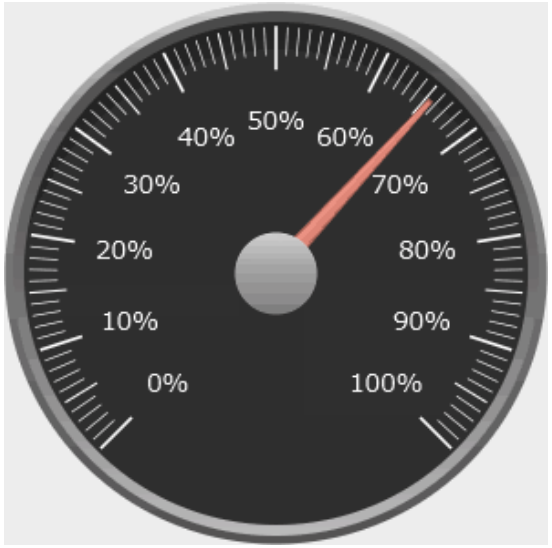
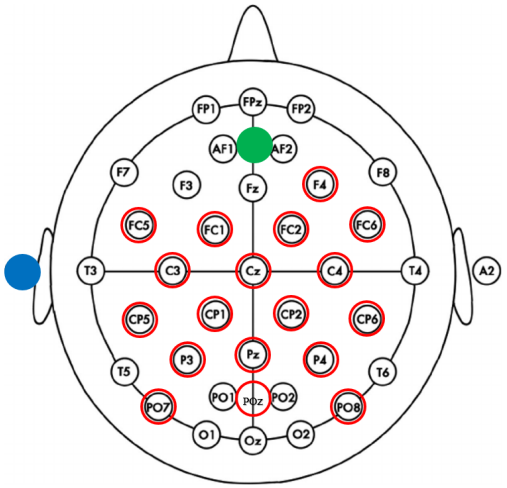


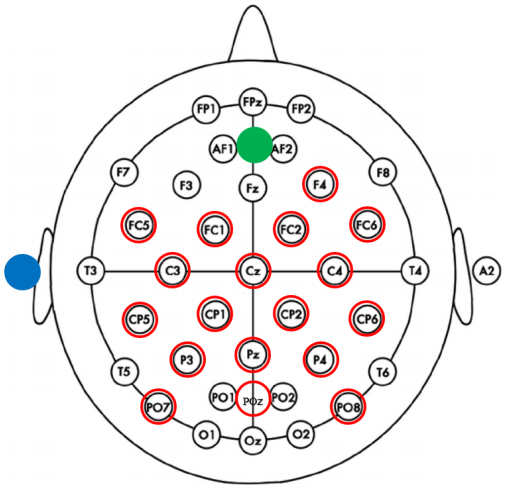
Feasibility Study : Cue-Driven Recording

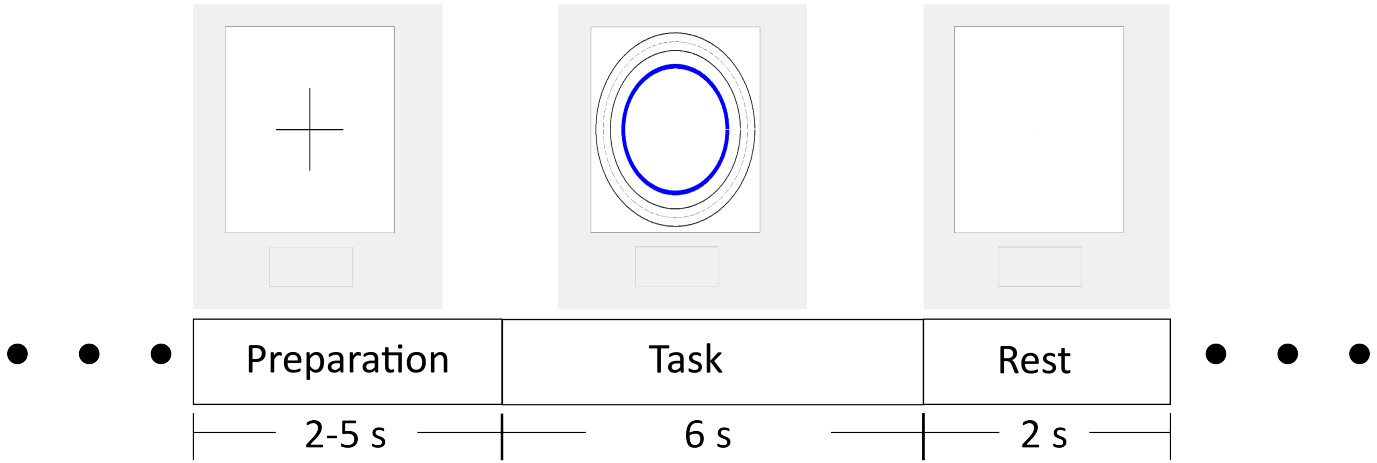
- EEG : 18 Channels
- 256 Hz, 0.1-100 Hz BPF
- Grip force, Forearm EMG



Feasibility Study : Cue-Driven Recording

- EEG : 18 Channels
- 256 Hz, 0.1-100 Hz BPF
- Grip force, Forearm EMG
- 21 cues/run, 1 run/effort level
- Left + right handed runs, randomized control cues
- **8 Healthy Subjects (7 male)**



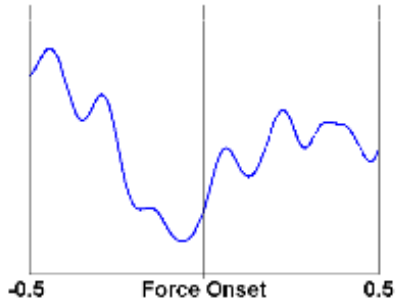


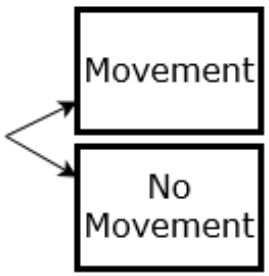
2-Stage Model

Stage 1

Movement Detection

1. Extract ERPs from each movement cue
2. Split ERPs into training and testing sets
3. Obtain ERP template from training set
4. Compute ρ_{xy} with sliding window testing set
5. Use a threshold to detect movement onset

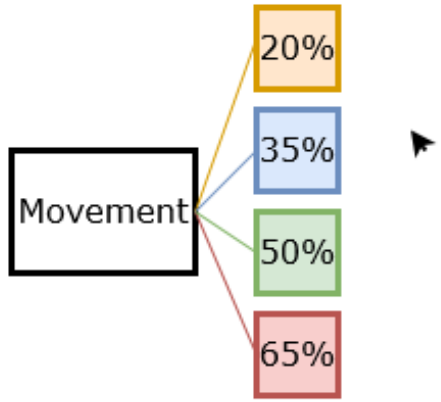




Stage 2

Graded Effort Classification

1. Use movement onset from Stage 1
2. Extract features reflecting SMR modulation
3. Classify each movement with logistic regression
4. Evaluate performance



Movement Detection

Dominant Hand

- Detections : **86.33% (4.76)**

Non-Dominant Hand

- Detections : **88.09% (6.10)**

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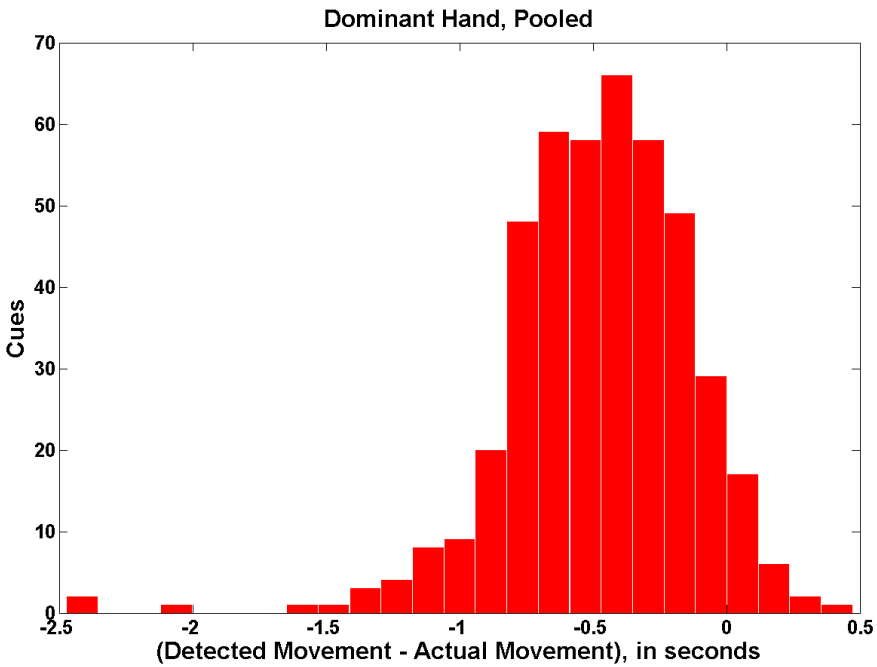

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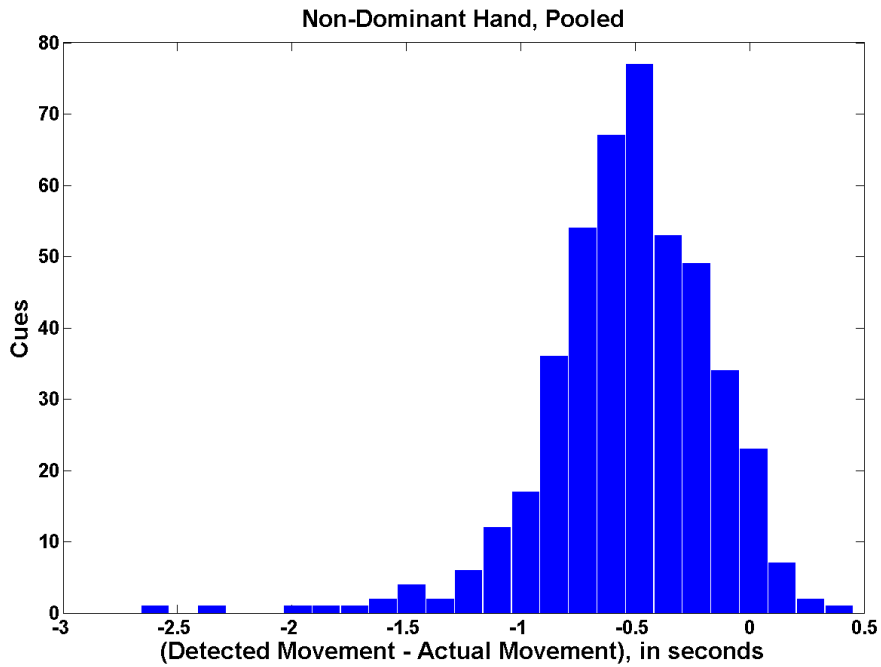

Graded Effort Classification

Chance Level : 25%

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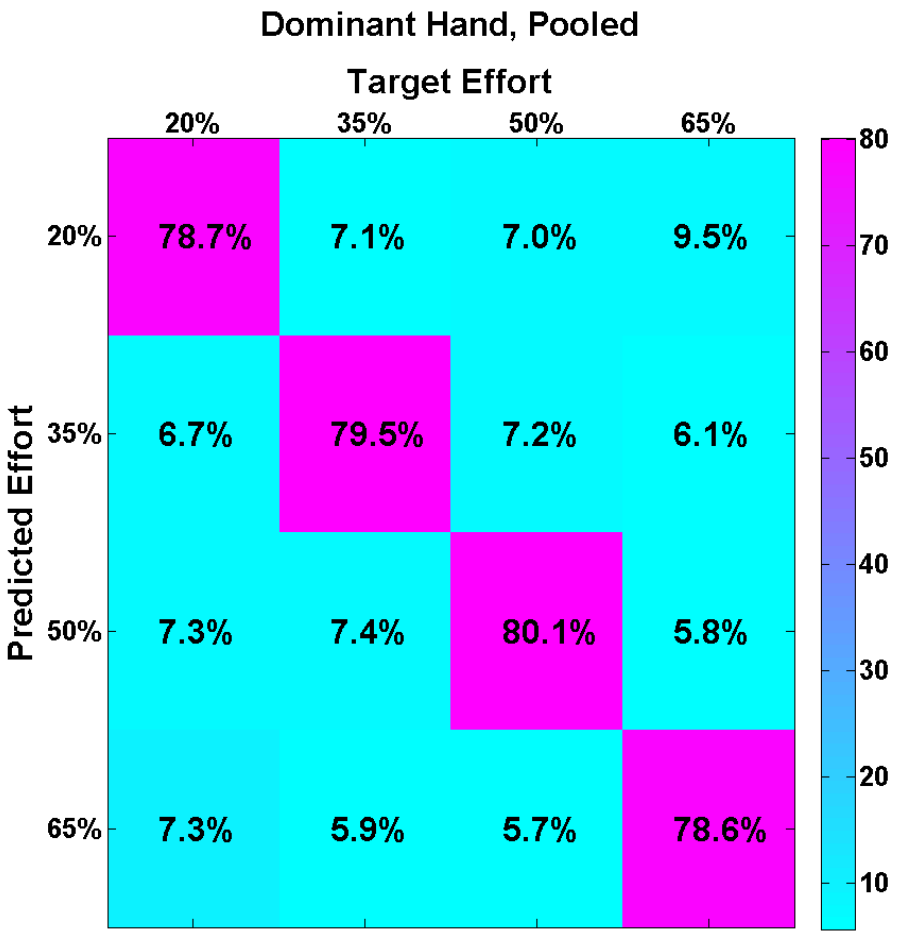

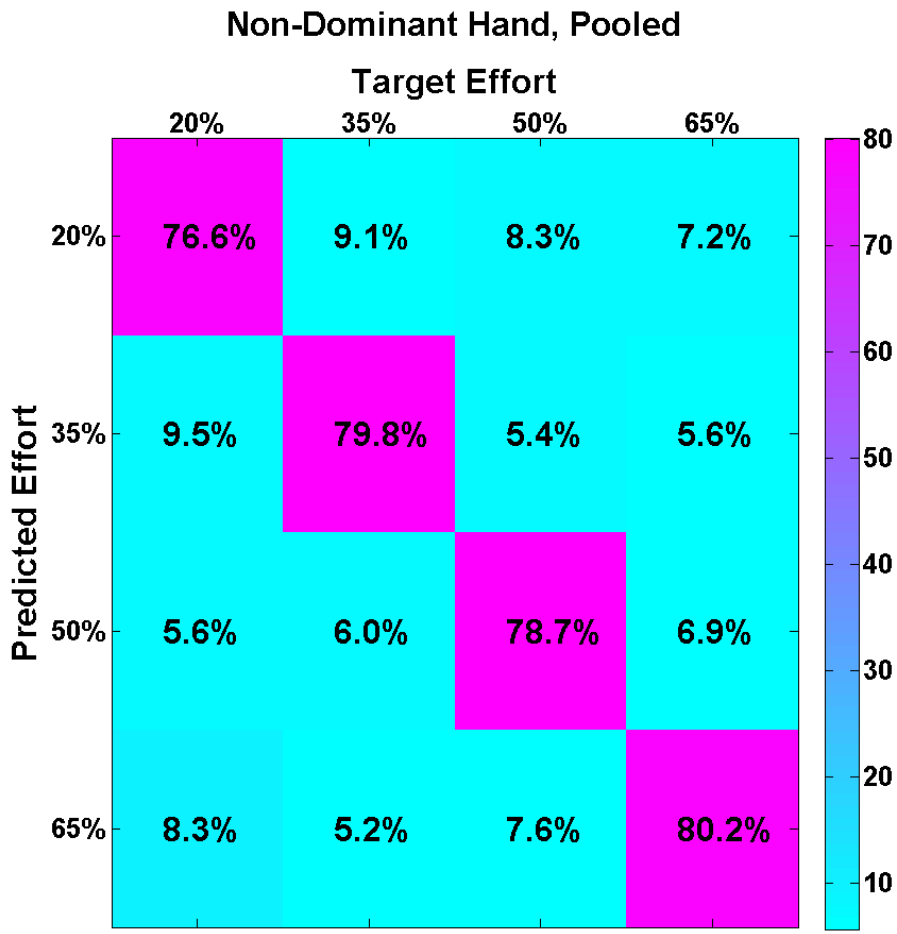

Simulated Online Performance

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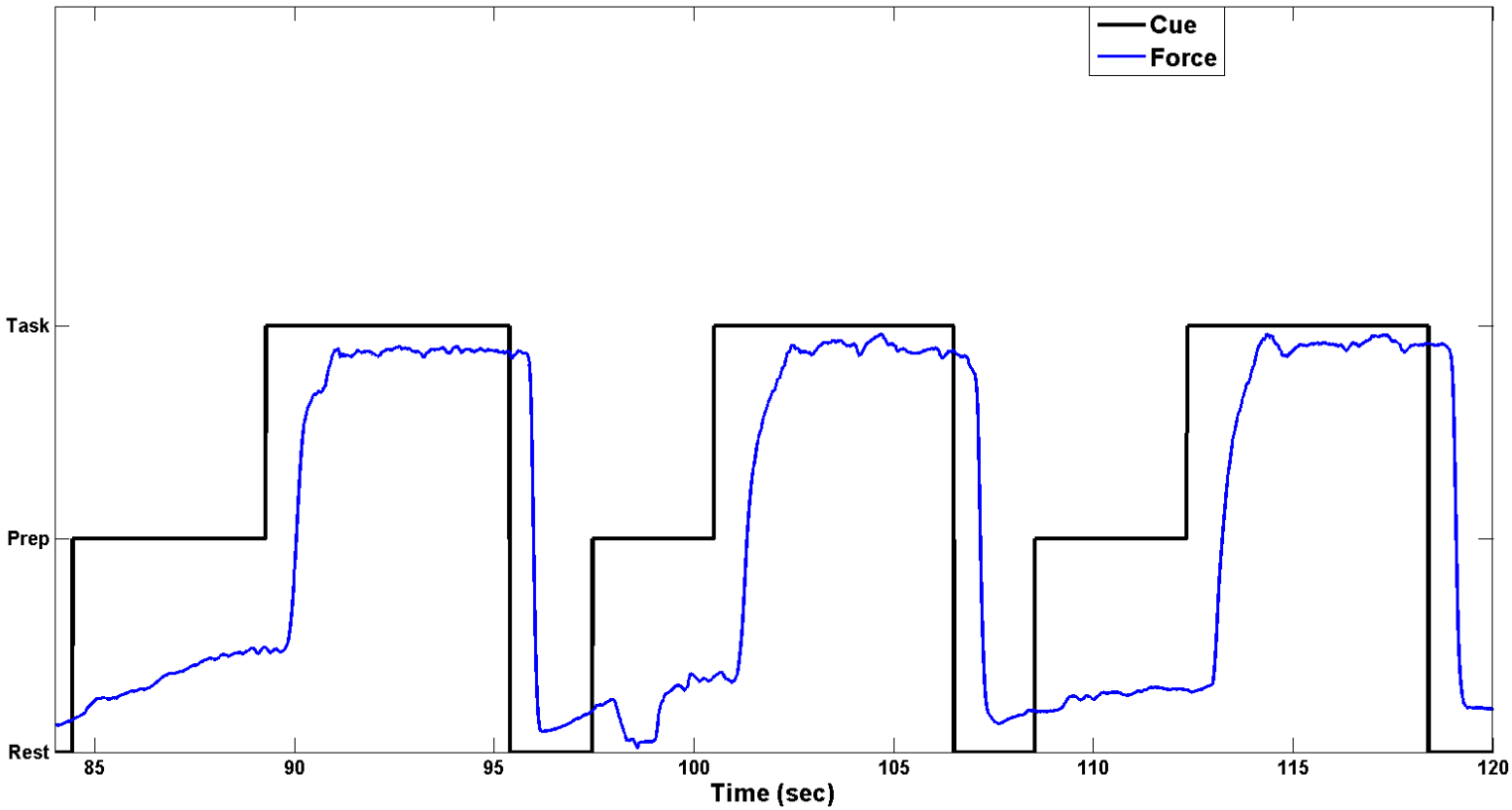

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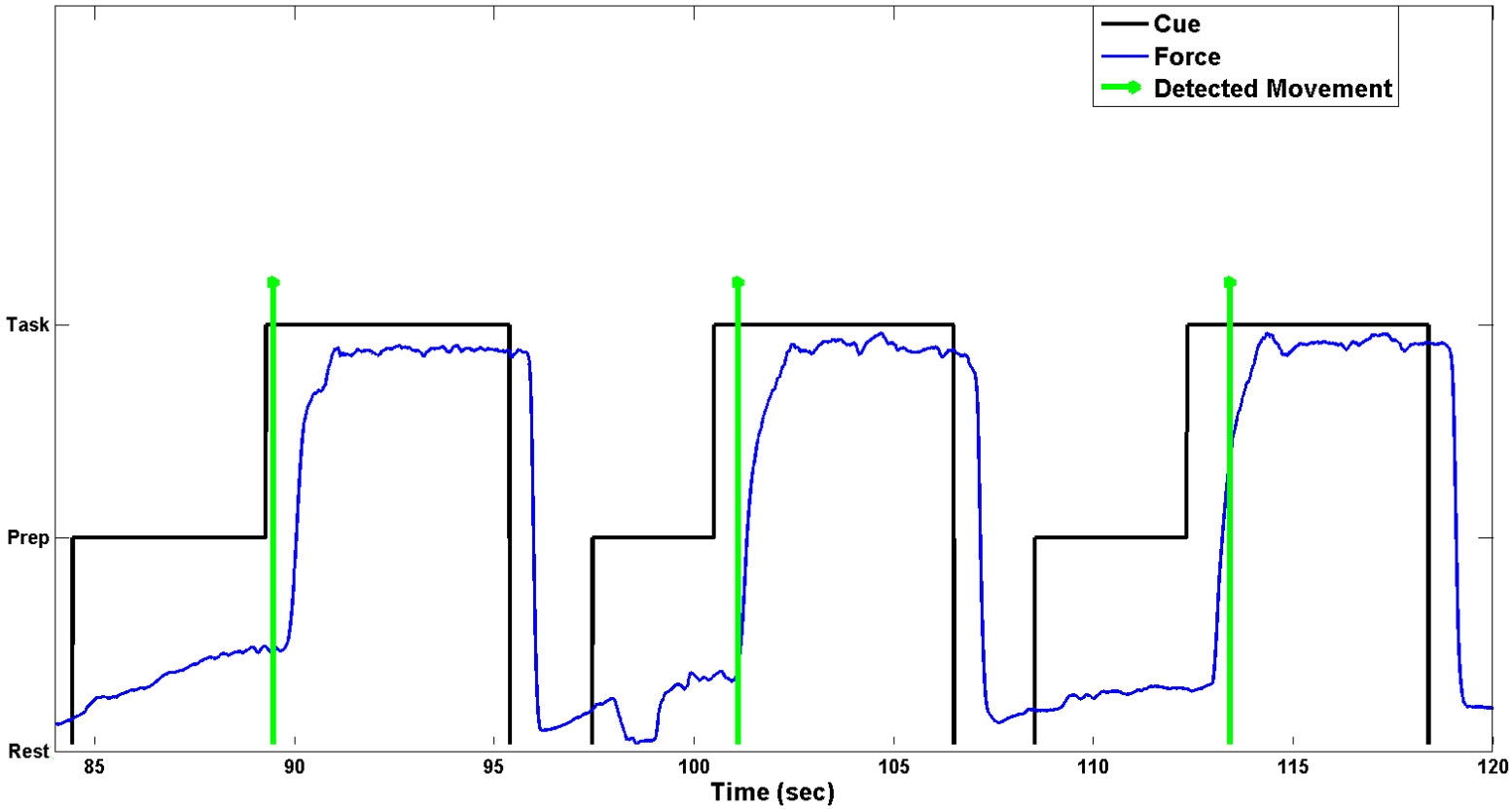

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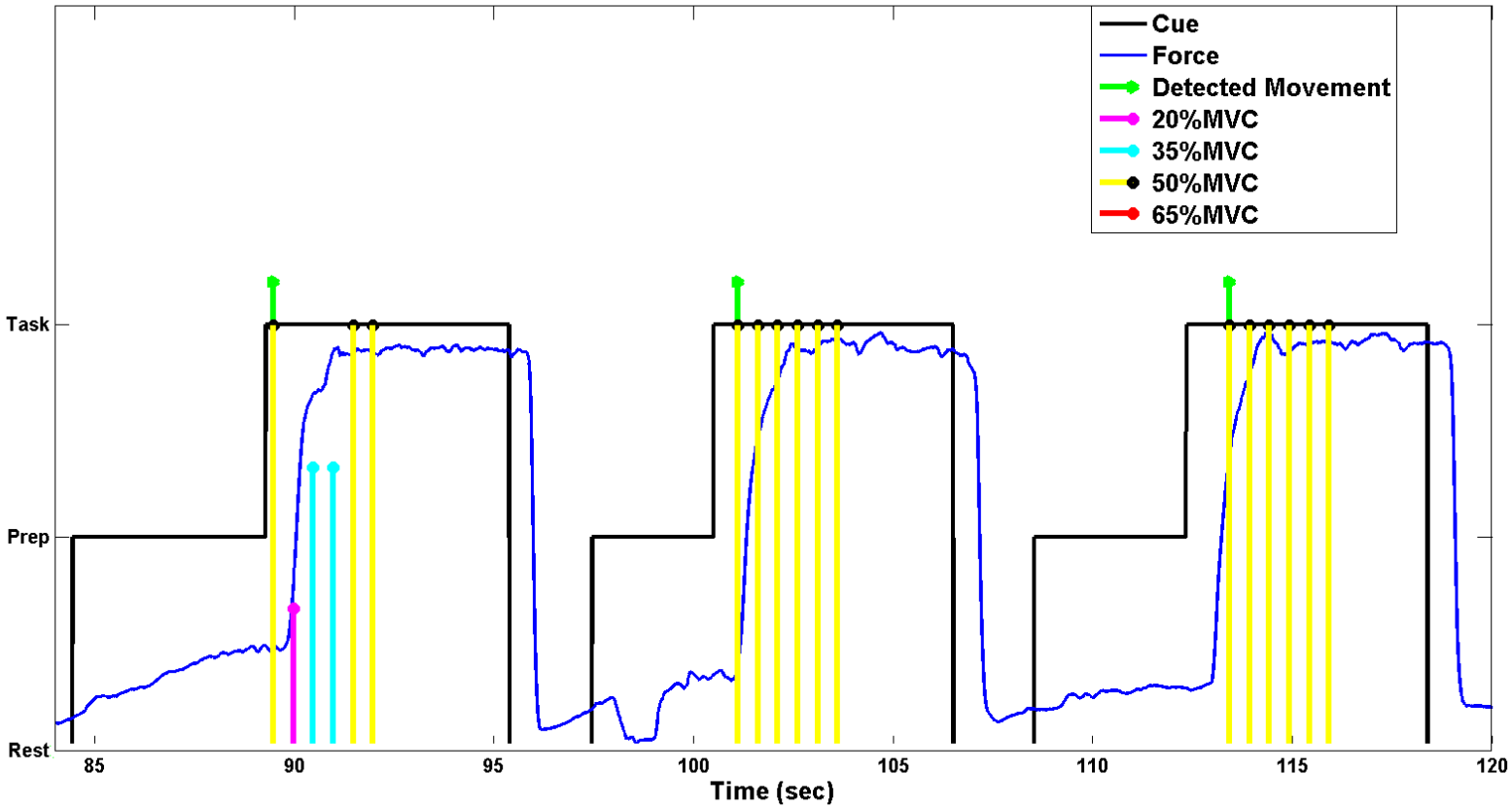

Study Limitations and Future Work

Study Limitations

- n = 8 subjects
- Offline Model
- Actual Force

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Future Work

- Optimize Model
- Online BMI
- Motor Imagery

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Acknowledgments

University of Kentucky Neural Systems Lab

Sridhar Sunderam, PhD

- Amir Al-Bakri
- Asma'a Ajwad
- Dillon Huffman
- Hao Wang, PhD
- Matt Ballard
- Sarah Thomas

Advisory Committee

- Bruce O'Hara, PhD
- Guoqiang Yu, PhD
- Kevin Donohue, PhD

National Science Foundation

Grant 1539068

BMES

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Summary...Questions ?

Utilize natural control signals

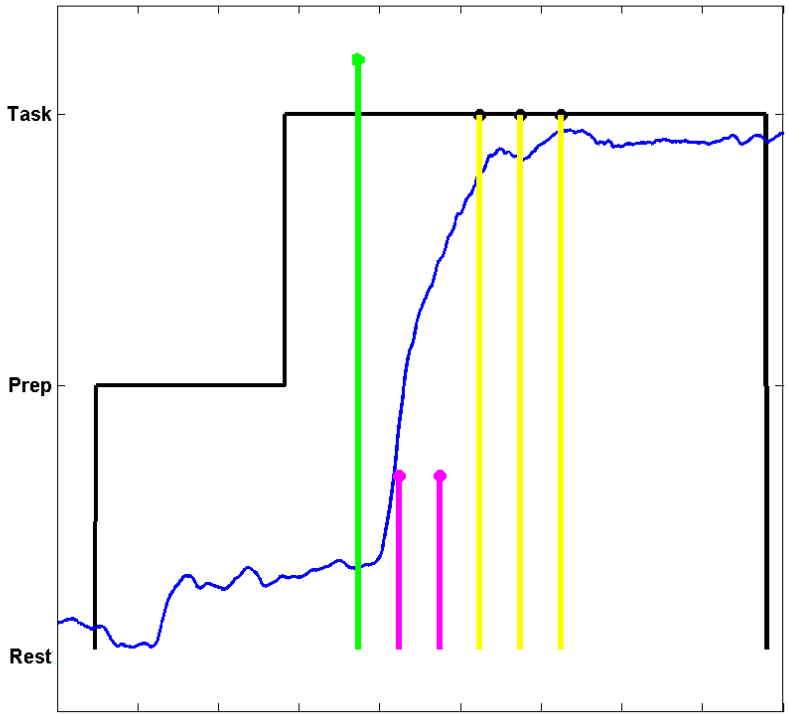
- Graded motor response

Detect Movement and Predict Level of Effort

- Graded effort = increased number of classes

Future Work : Online + Motor Imagery

- Effort prediction based on imagination



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