EEG4Home

A Human-In-The-Loop Machine Learning Model for EEG-Based Brain-Computer Interfaces

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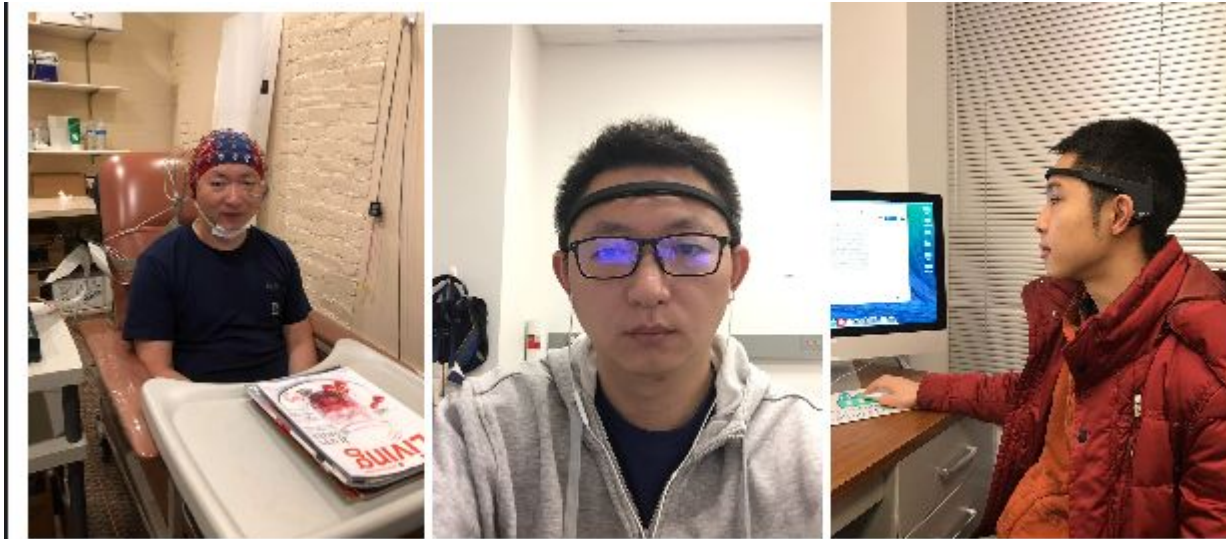
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A STEVEN SPIELBERG FILM
READY PLAYER ONE

Motivation

Machine Learning + Brain-Computer Interfaces,   Clinical vs. non-clinical

More datasets? From healthy users? From everyday life?

Introduction

Research Questions:

- Develop an easy-to-use EEG based BCI framework
- For non-expert healthy end-users
- Use Machine Learning to classify everyday learning tasks

Literature Review

Lotte 2018, Machine Learning + BCI, Current progress and research questions

Lotte, F., Bougrain, L., Cichocki, A., Clerc, M., Congedo, M., Rakotomamonjy, A., & Yger, F. (2018). A review of classification algorithms for EEG-based brain–computer interfaces: a 10 year update. *Journal of neural engineering*, *15*(3), 031005.

Craik 2019 and Roy 2019, Deep Learning + BCI

Craik, A., He, Y., & Contreras-Vidal, J. L. (2019). Deep learning for electroencephalogram (EEG) classification tasks: a review. *Journal of neural engineering*, *16*(3), 031001.

Roy, Y., Banville, H., Albuquerque, I., Gramfort, A., Falk, T. H., & Faubert, J. (2019). Deep learning-based electroencephalography analysis: a systematic review. *Journal of neural engineering*, *16*(5), 051001.

EEGEyeNet, A 2021 dataset, EEG + Eye Tracking, 300+ participants

Kastrati, A., Plomecka, M. B., Pascual, D., Wolf, L., Gillioz, V., Wattenhofer, R., & Langer, N. (2021, June). EEGEyeNet: a Simultaneous Electroencephalography and Eye-tracking Dataset and Benchmark for Eye Movement Prediction. In *Thirty-fifth Conference on Neural Information Processing Systems Datasets and Benchmarks Track (Round 1)*.
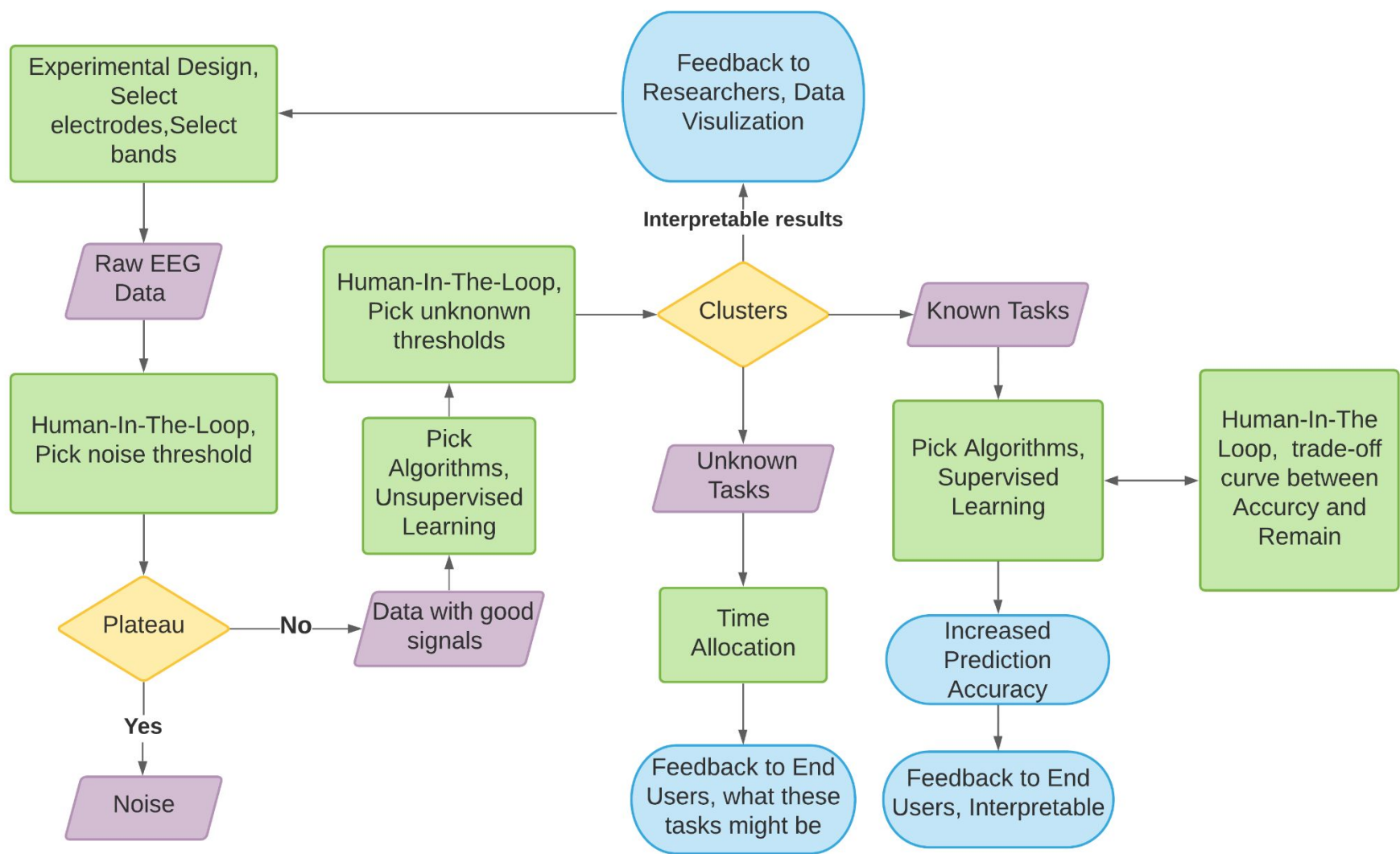
EEG headset devices [Portillo-Lara_2021,Sawangjai_2020, and Ienca_2018]

Device Name	Manufacturer	Price*	Channels	Main Functions advertised
Muse 2	InteraXon(Canada)	$220	4	Meditation, self-assessment
Muse S	InteraXon(Canada)	$300	4	Meditation, self-assessment, Sleep
Insight	Emotiv Systems	$300	5	Self-assessment, device control
Epoc+	Emotiv Systems	$700	14	Self-assessment, device control
MindWave Mobile 2	Neurosky	$100	1	Meditation,Self-assessment, Gaming, device control
'Mark IV'	Open BCI	$500 to 600	8 to 16	(unassembled), self-assessment open-development,

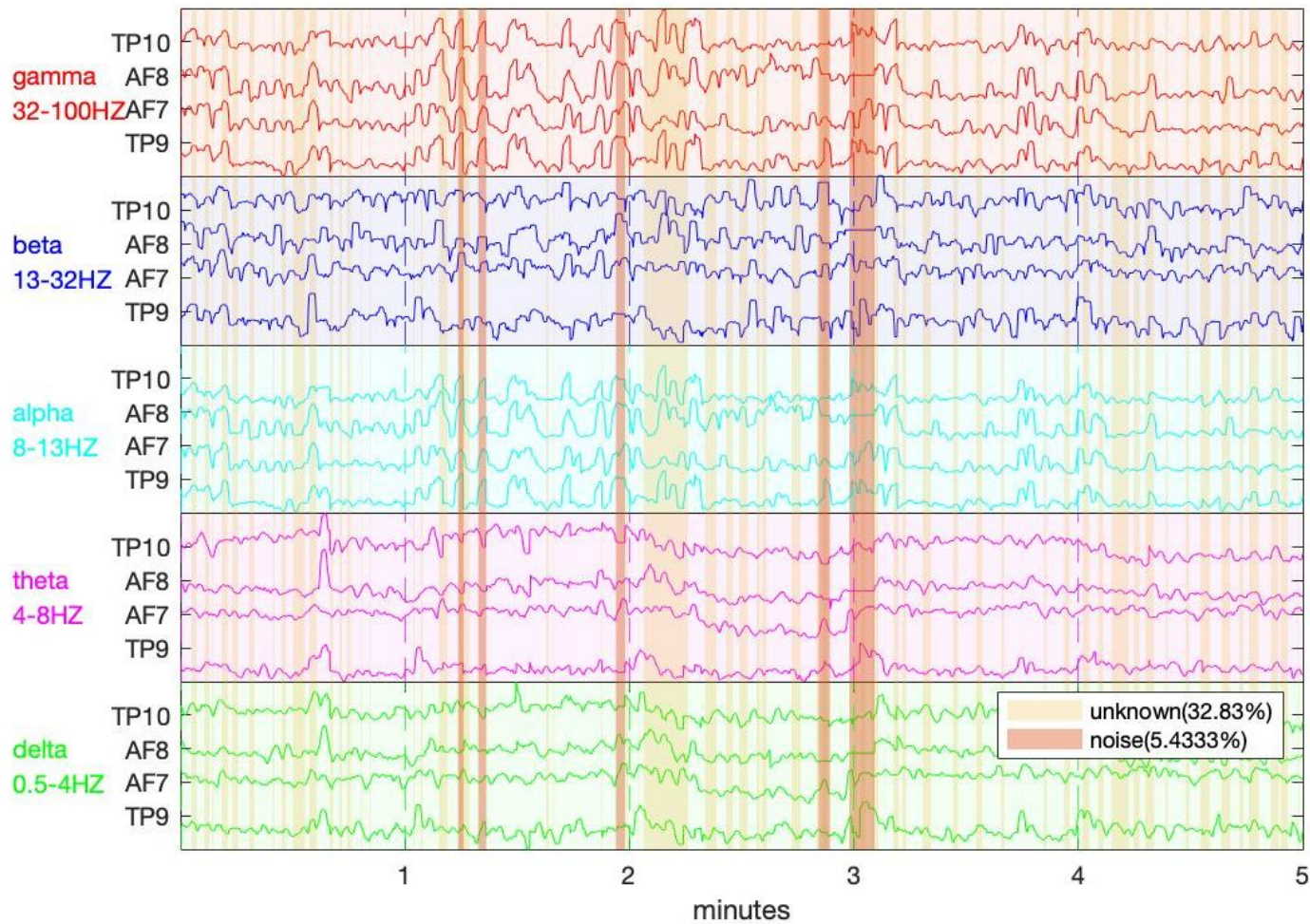* price, as of Jun 20, 2020. From the Manufacturers' official websites.

EEG Experiments

Exp (Task)	(1)	(2)	(3)	(4)	(5)
[19]	Math	Close-eye Relax	Read	Open-eye Relax	None
[22]	Python Passive	Math Passive	Python Active	Math Active	None
[21]	Read	Write Copy	Write Answer	Type Copy	Type Answer
[20]	Think	Count	Recall	Breathe	Draw

```
┌─────────────────┐          ┌─────────────────┐
│ Experimental    │◄─────────│ Feedback to     │
│ Design,         │          │ Researchers, Data│
│ Select          │          │ Visulization    │
│ electrodes,Select│         │                 │
│ bands           │          └─────────────────┘
└─────────────────┘                   ▲
        │                  Interpretable results
        ▼                             │
┌─────────────────┐  ┌─────────────────┐  ◆        ┌─────────────────┐
│ Raw EEG         │  │ Human-In-The-Loop,│ Clusters │ Known Tasks     │
│ Data            │  │ Pick unknonwn   │──►        │                 │
│                 │  │ thresholds      │           └─────────────────┘
└─────────────────┘  └─────────────────┘
```

Experimental Design, Select electrodes, Select bands

Raw EEG Data

Human-In-The-Loop, Pick noise threshold

Plateau — **No** → Data with good signals

Yes

Noise

Pick Algorithms, Unsupervised Learning

Human-In-The-Loop, Pick unknonwn thresholds

Feedback to Researchers, Data Visulization

Interpretable results

Clusters

Unknown Tasks

Time Allocation

Feedback to End Users, what these tasks might be

Known Tasks

Pick Algorithms, Supervised Learning

Human-In-The-Loop, trade-off curve between Accurcy and Remain

Increased Prediction Accuracy

Feedback to End Users, Interpretable

Detect Noise

subject 1 session 1

Accuracy

Data Remain

Data Remain and Accuracy VS Cluster Number and Threshold
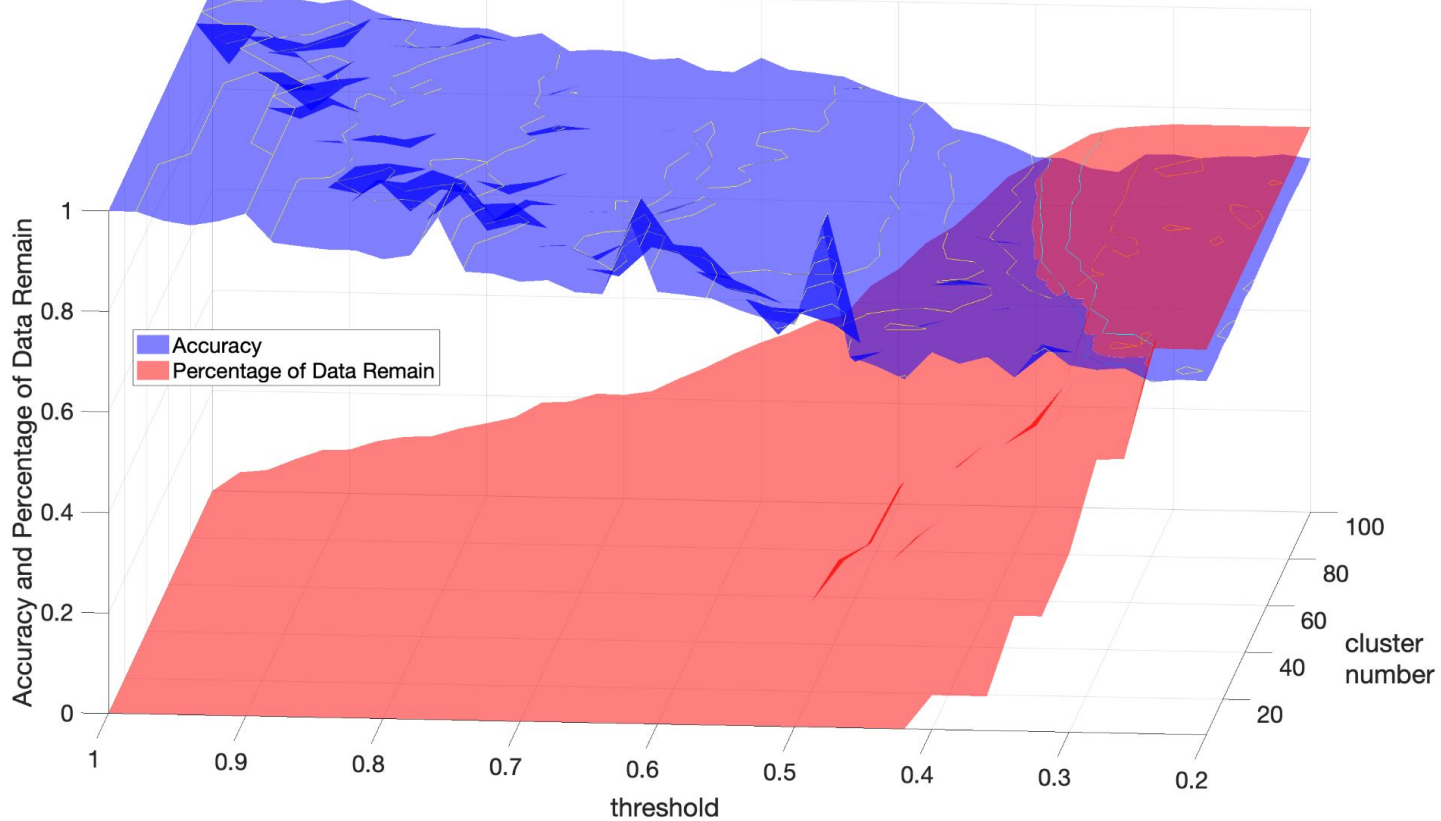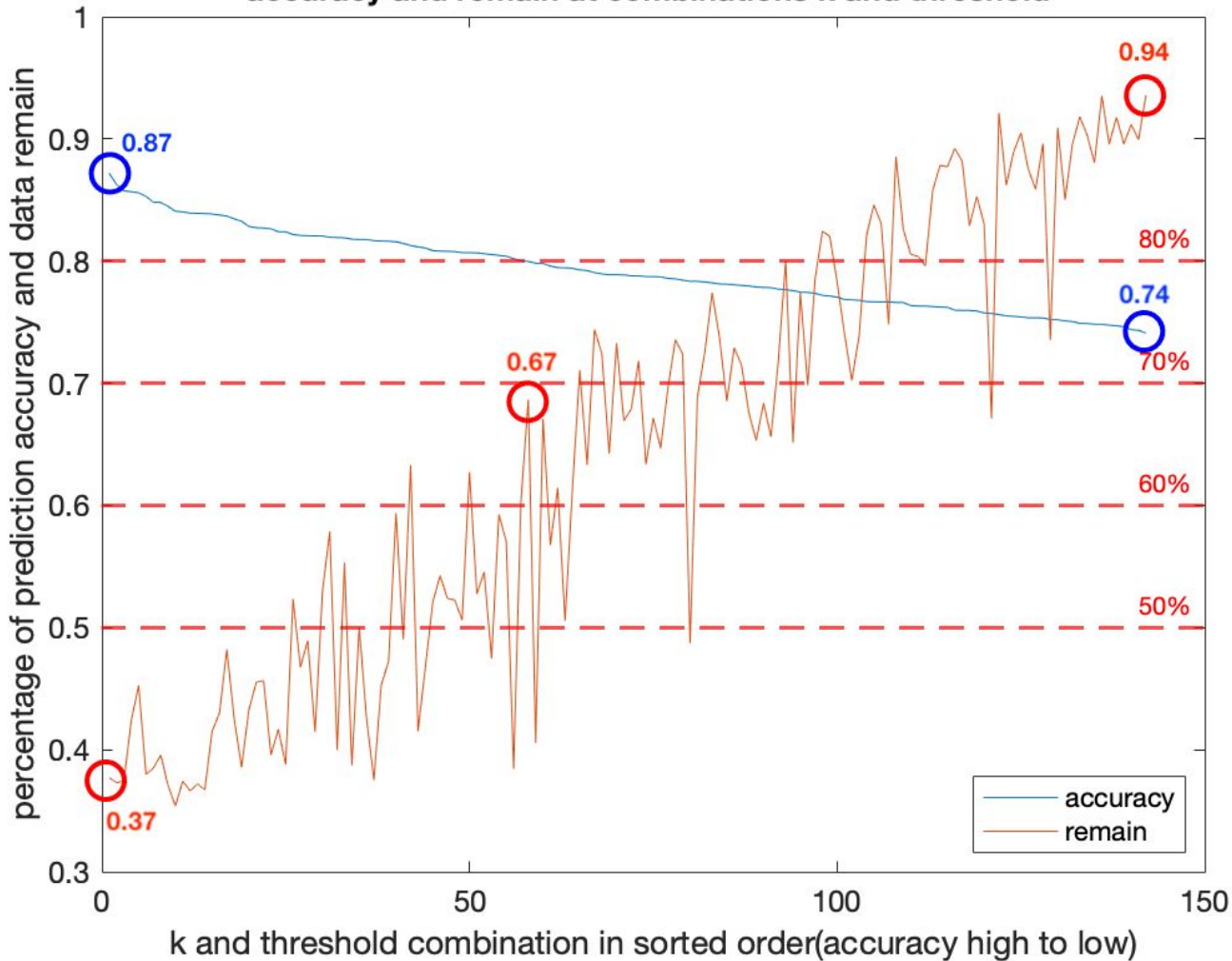
Trade Off
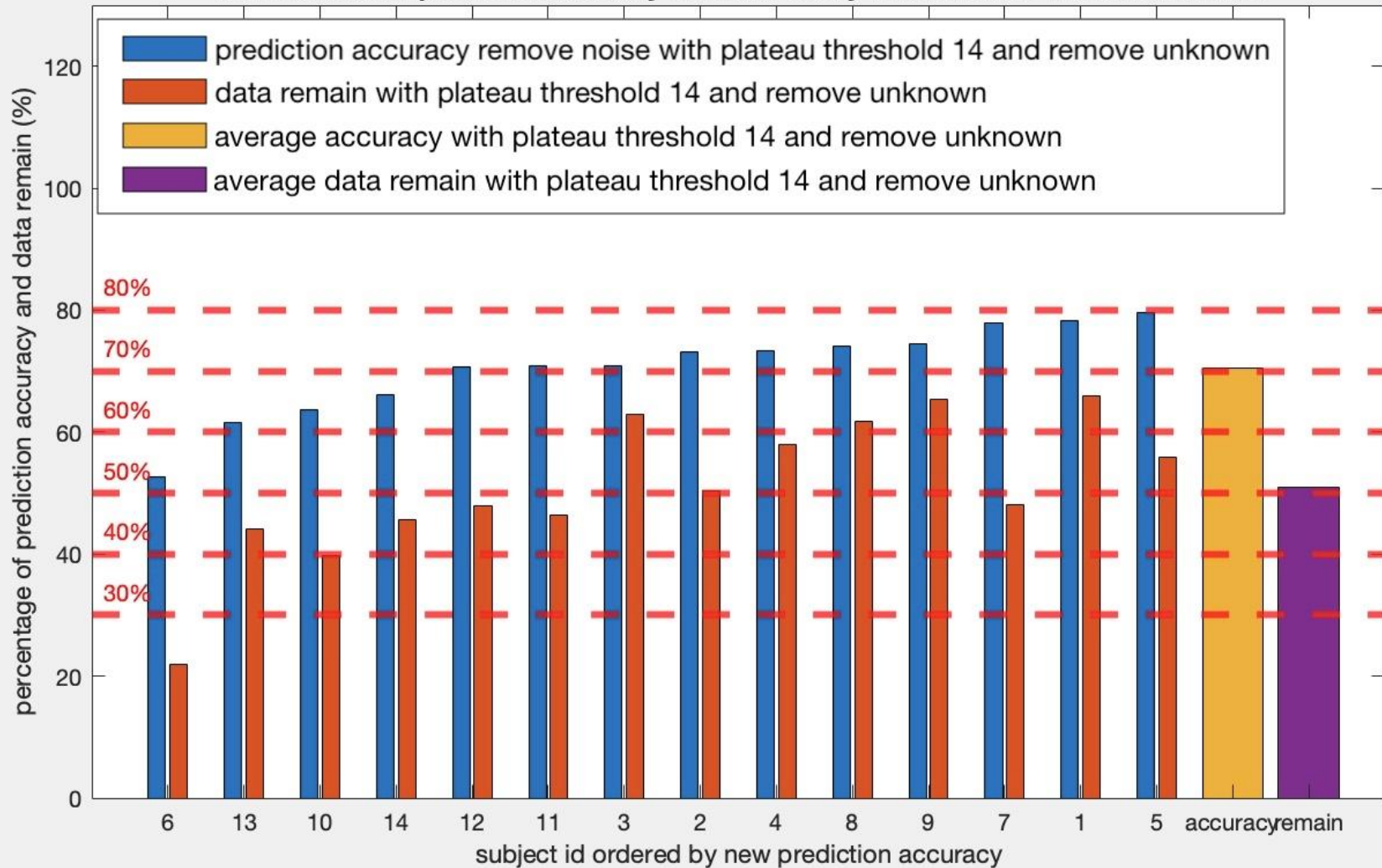
Accuracy

Data Remain

Known

Unknown

Noise
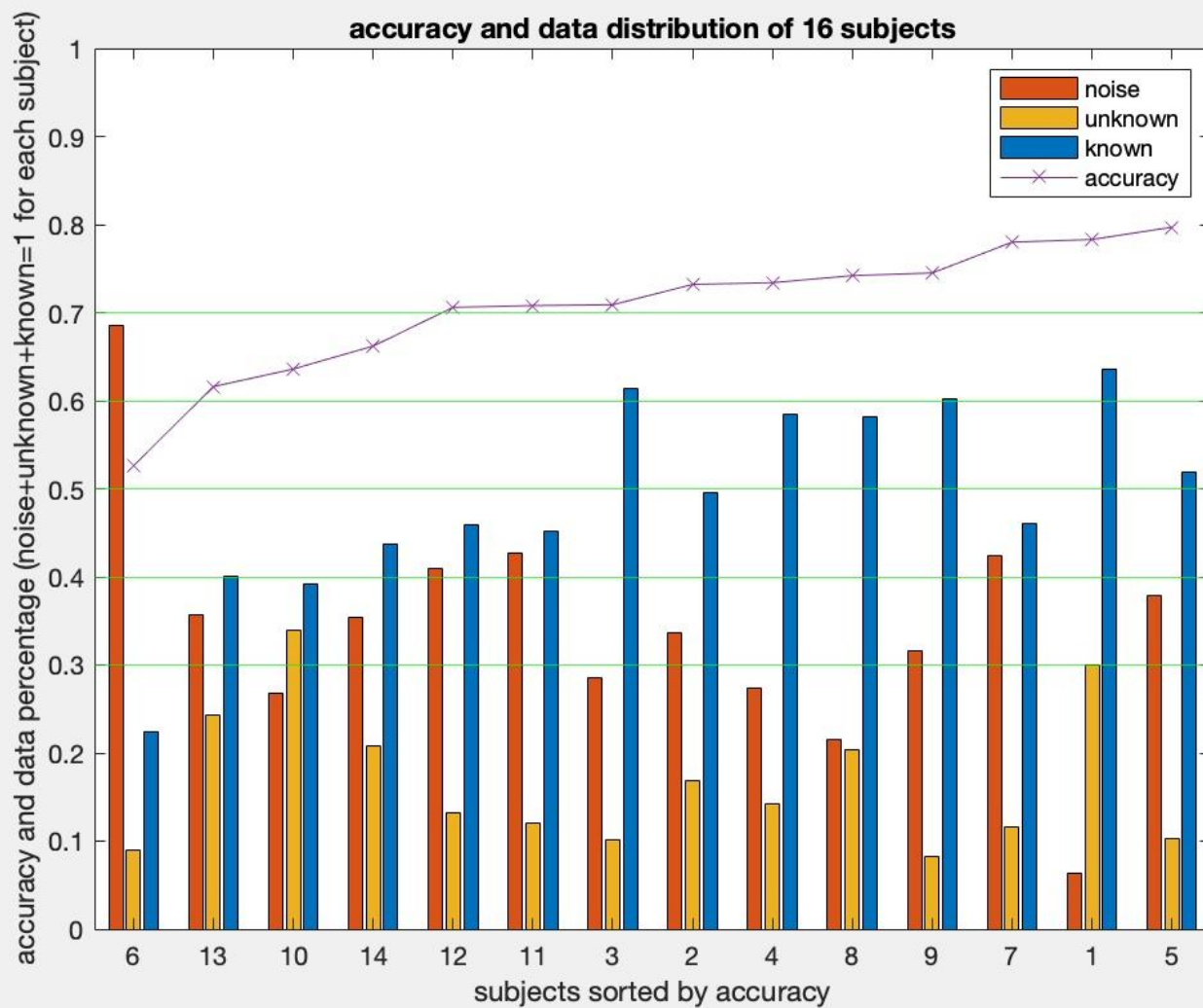
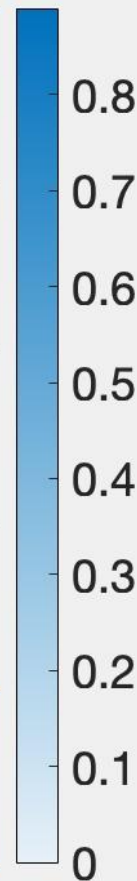data remain and prediction accuracy with data cut by time in 7 folds with two methods

prediction accuracy on each task

Feedback To End-Users

Actual Task

	T1	T2	T3	T4	T5
T1:R	0.75	0.09	0.03	0.11	0.02
T2: WC	0.11	0.69	0.07	0.11	0.02
T3: WA	0.05	0.04	0.82	0.05	0.04
T4: TC	0.12	0.05	0.03	0.76	0.04
T5: TA	0	0	0.07	0.04	0.89

Predicted Task

Conclusion

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Human-In-The-Loop Machine learning

Reasonable high prediction accuracy

Interpretable results

EEG-based Brain-Computer Interfaces

Questions?

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Take-away Message

Four Experiments
Sixty Participants
Everyday learning tasks
Consumer-grade headset

Baseline Algorithms
K-Means to remove noise
Random Forest, CNN, RNN
Visual feedback for users

Thank you so much!