



Predicting Parkinson's Disease Behavioral State from Neural & Kinematic Data

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Background

- Freezing of gait is a common symptom in Parkinson's disease (PD) that leads to falls and reduced mobility
- Treatment is limited due to a lack of understanding in the neuro-biomechanical mechanisms of impaired walking [1]
- Predicting freezing of gait from neural signals would allow for closed loop brain stimulation therapy to improve gait

Objective: Predict PD behavior state from neural data while walking in ellipses & figures eights of turning & barrier course

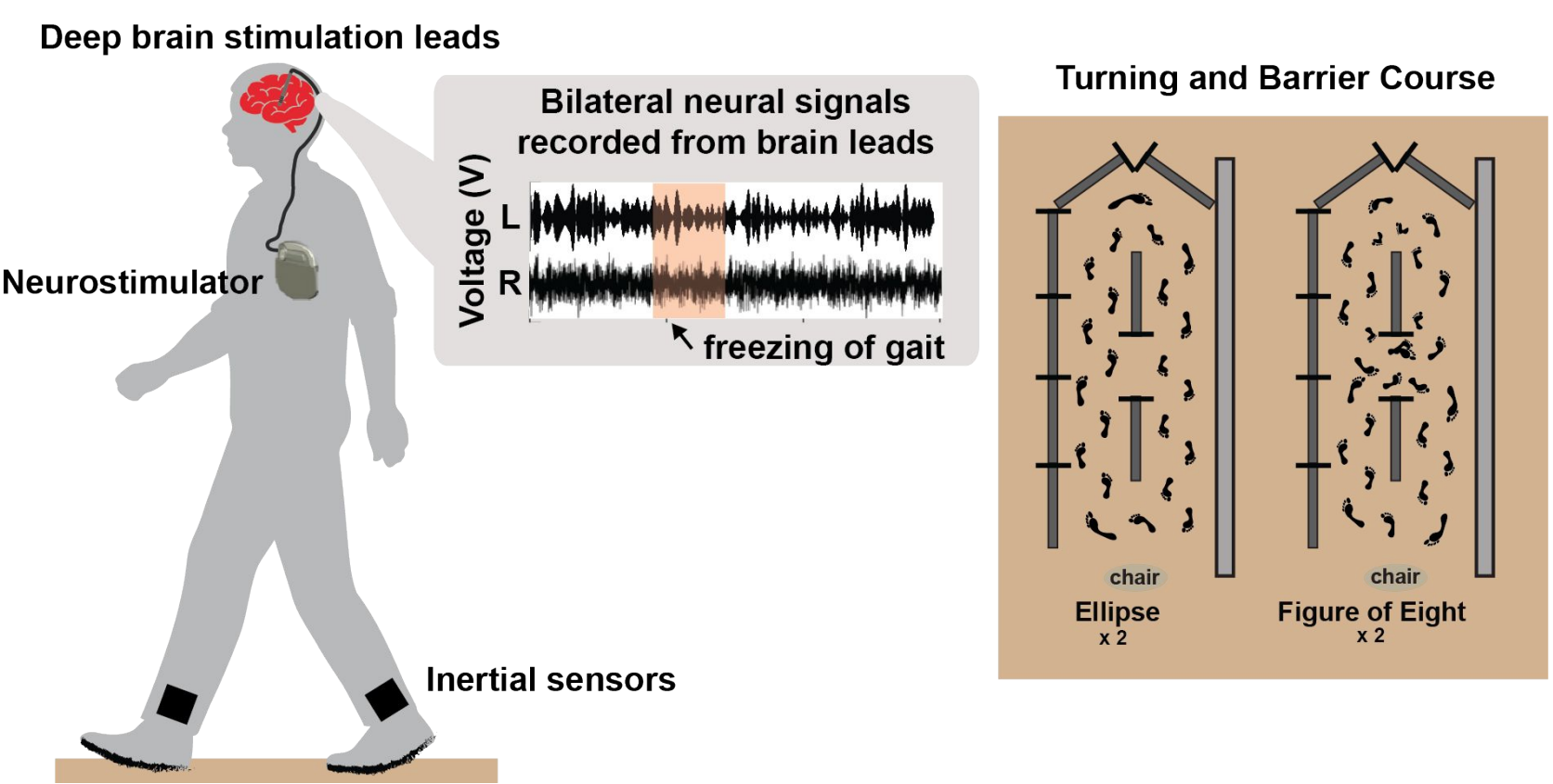


Figure 1: Neural and kinematic signals from patient walking in turning and barrier course.

Dataset & Features

- Dataset:** 4.4 minutes (>100k examples) of walking data from single patient walking around a turning and barrier course designed to elicit freezing (Fig. 1) [2] (data shared from the Bronte-Stewart Lab)
- Features:**
 - raw neural signals (voltage time series, 422 Hz)
 - FFT neural signals (power time series, 4 Hz bins)
 - “spec3D_beta” - beta band (12-28 Hz)
 - patient turning toward more PD-affected side of body
 - patient experiencing tremor
 - arrhythmicity (coefficient of variation of stride time)*
 - neurologist-rated identification of freezing*
 - part of the course walking in (figure eight/ellipse)*
- Outputs:** We reframed the problem by changing the output of our model, features marked * above were outputs at different iterations through this evolution

References

[1] Anidi, C., O'Day, J. J., Anderson, R. W., Afzal, M. F., Syrkin-Nikolau, J., Velisar, A., & Bronte-Stewart, H. M. (2018). Neuromodulation targets pathological not physiological beta bursts during gait in Parkinson's disease. *Neurobiology of disease*, 120, 107-117.
[2] Syrkin-Nikolau, J., Koop, M. M., Prieto, T., Anidi, C., Afzal, M. F., Velisar, A., ... & Bronte-Stewart, H. (2017). Subthalamic neural entropy is a feature of freezing of gait in freely moving people with Parkinson's disease. *Neurobiology of disease*, 108, 288-297.

Methods

Models

- Logistic Regression
- Long Short-Term Memory Network (LSTM)
- 1-Dimensional Convolutional Neural Network (1D CNN)

Model Selection

- Input: 100-sample windows of time series neural data (varied hand-engineered forms) & behavioral trial features
- Output: probability of an ellipse (0) or figure eight (1)
- Binary cross-entropy loss
- Parameter-tuning: 100+ experiments hand-tuning parameters
- Holdout cross-validation
- Metrics
 - Mean area under the receiver operating curve (AUC)
 - Accuracy at optimal threshold

Results

Model	Mean AUC (SD)	Accuracy at Optimal Threshold
Logistic Regression	0.65 (0.10)	0.60
LSTM	0.65 (0.10)	0.61
Conv32	0.62 (0.06)	0.60
Conv4	0.65 (0.10)	0.62
Conv4 with regularization	0.70 (0.08)	0.69

Table 1: Model performances and results of hyperparameter implementation and tuning

Highest-Performing Model

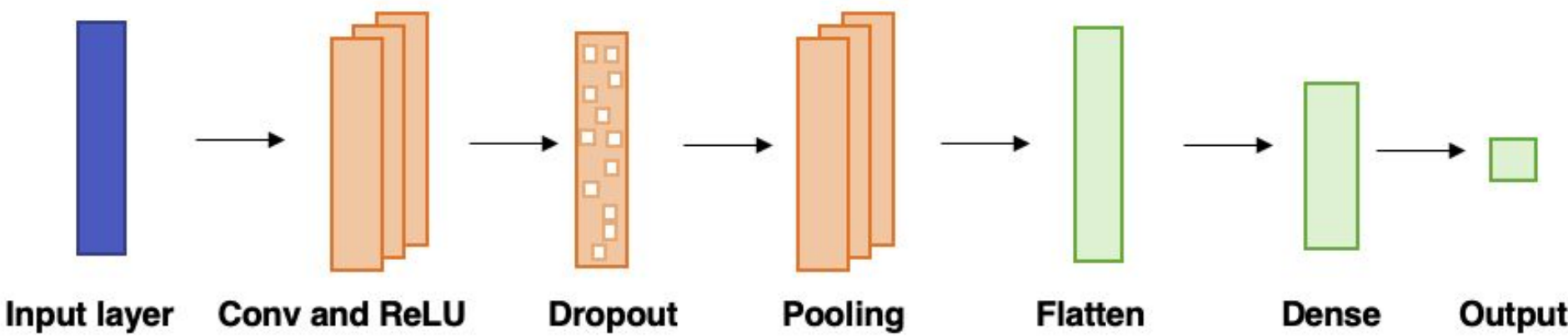


Figure 2: Final 1D CNN model architecture

- Input: hand-engineered features using spectrogram analysis and field knowledge
- 4-filter convolutional layer with kernel size of 10, L1 regularization, and ReLu activation
- 50% dropout layer during training
- MaxPool layer with a pool size of 4
- Dense layer with sigmoid activation

Results

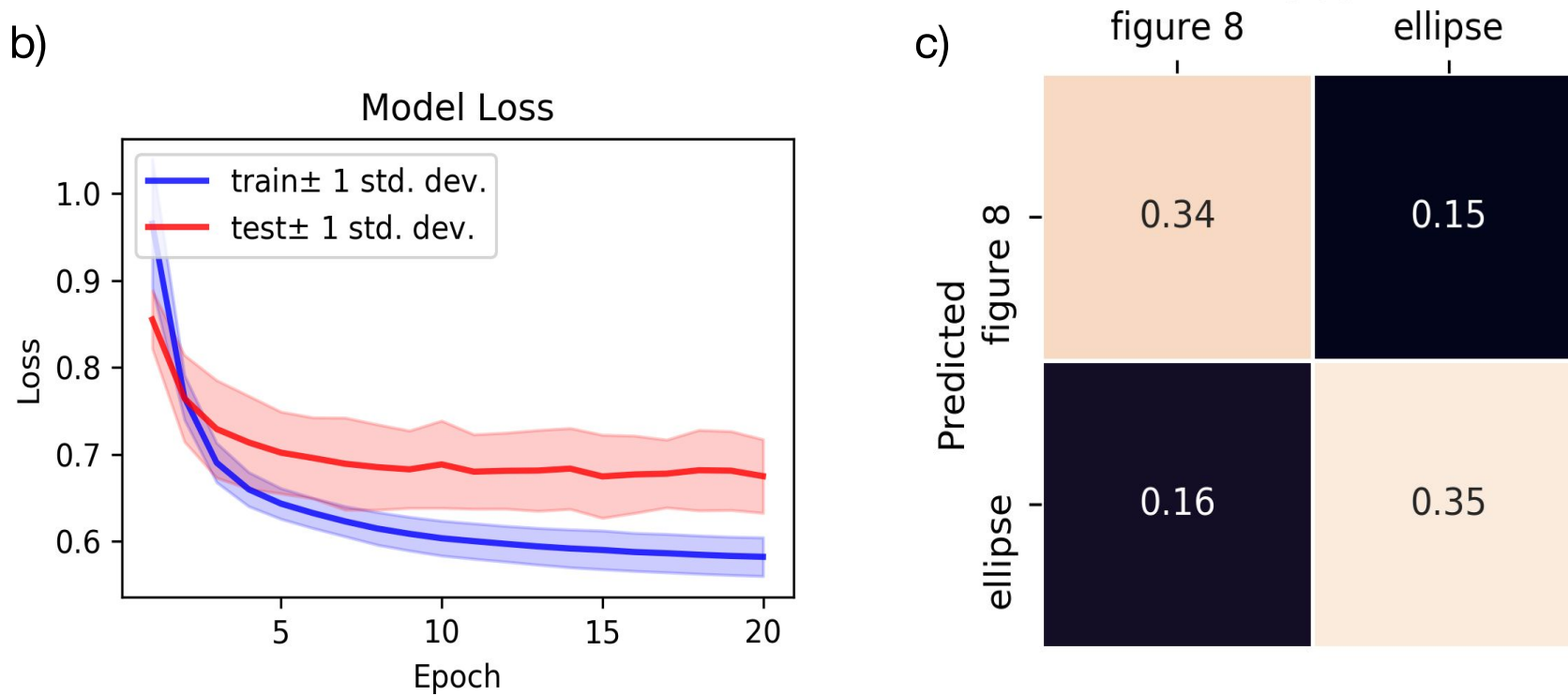
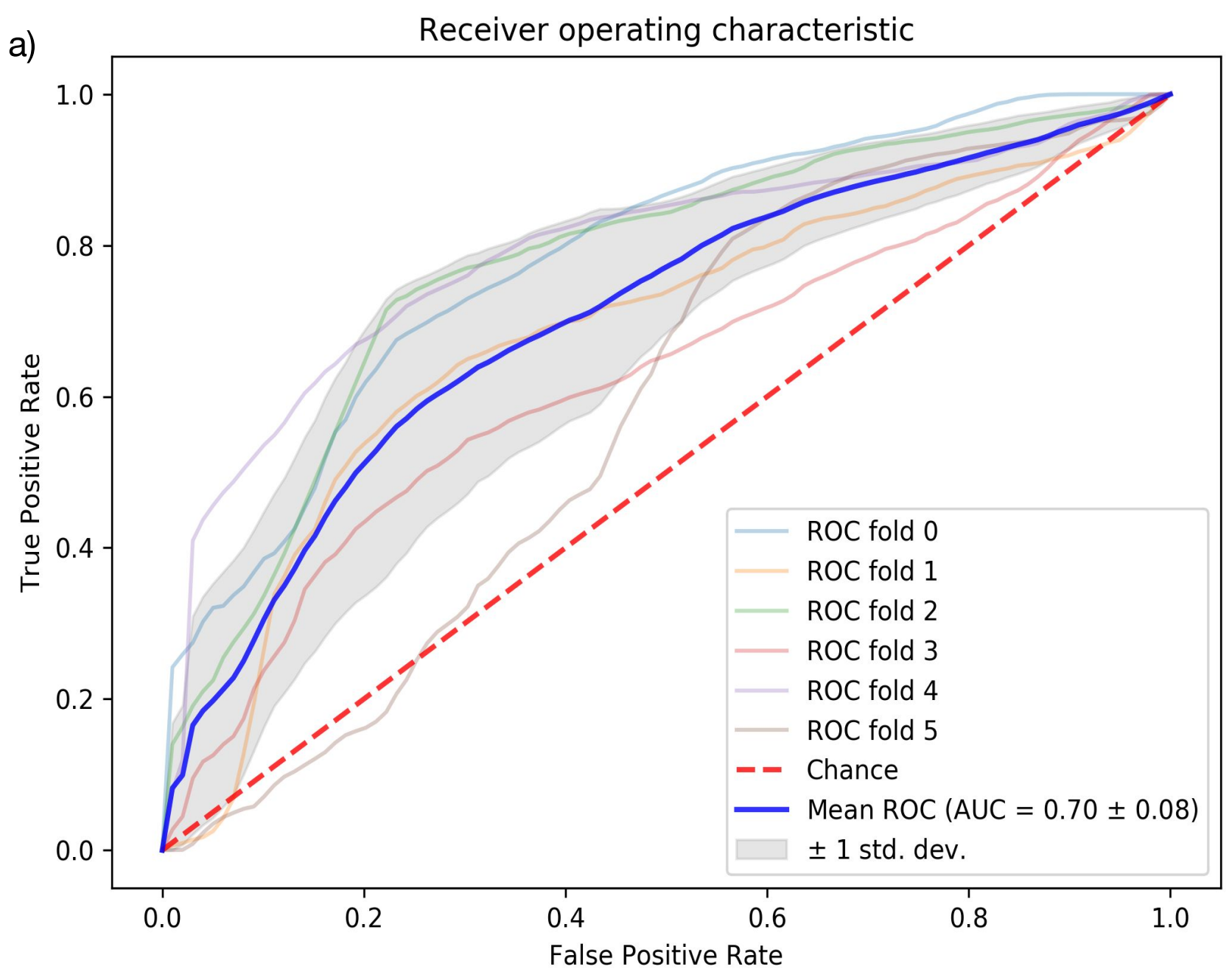


Figure 3: Highest-performing model results.

a) Receiver operating characteristic for holdout cross-validation.
b) Average training and test losses over all cross-validation folds.
c) Aggregate confusion matrix of holdout cross-validation folds.

Discussion

- Achieved mean AUC of 0.70
- Successful strategies: decreasing number of parameters; regularization
- Challenges: overfitting noisy, small dataset; learning from neural data

Next Steps

- Obtain objective measure of freezing as output
- Obtain more data (hours)