Deep learning fMRI classification of temporal codes during naturalistic movie viewing and memory recall

Matthew R. Johnson[a], Thomas P. O'Connell[b], Marvin M. Chun[b], & Marcia K. Johnson[b]

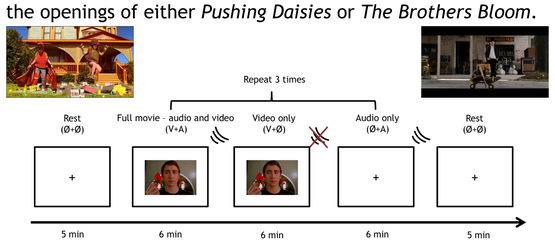
[a]University of Nebraska-Lincoln [b]Yale University

INTRODUCTION

- How accurately can we hope to decode the continuously varying contents of complex, naturalistic thoughts/percepts using fMRI?
- We use a new method from our group[1] that uses deep learning to classify whether two activity patterns are similar or different.
- We apply it to visual+auditory cortex activity during a novel, naturalistic movie viewing task featuring time-locked runs of episodic memory recall and imagery for the same information.

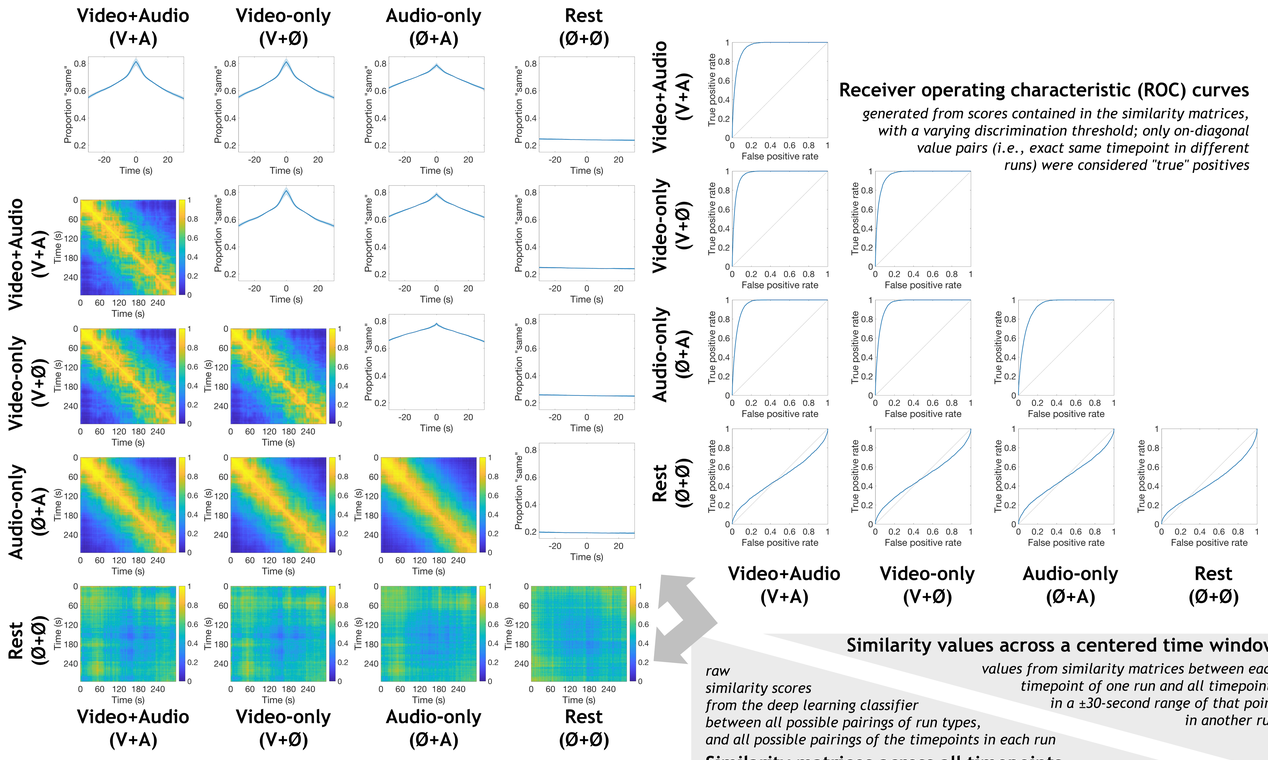
TASK DESIGN

- Participants (N=15) viewed & listened to one of two 6min films, the openings of either *Pushing Daisies* or *The Brothers Bloom*.



- Each viewing = one run. Participants saw the film intact (V+A), with only video (V+Ø), or with only audio (Ø+A), three times each. On non-intact runs, they were instructed to imagine the missing sensory modality from memory. 5min resting-state runs (Ø+Ø) were also collected at the beginning and end of the scan.

RESULTS



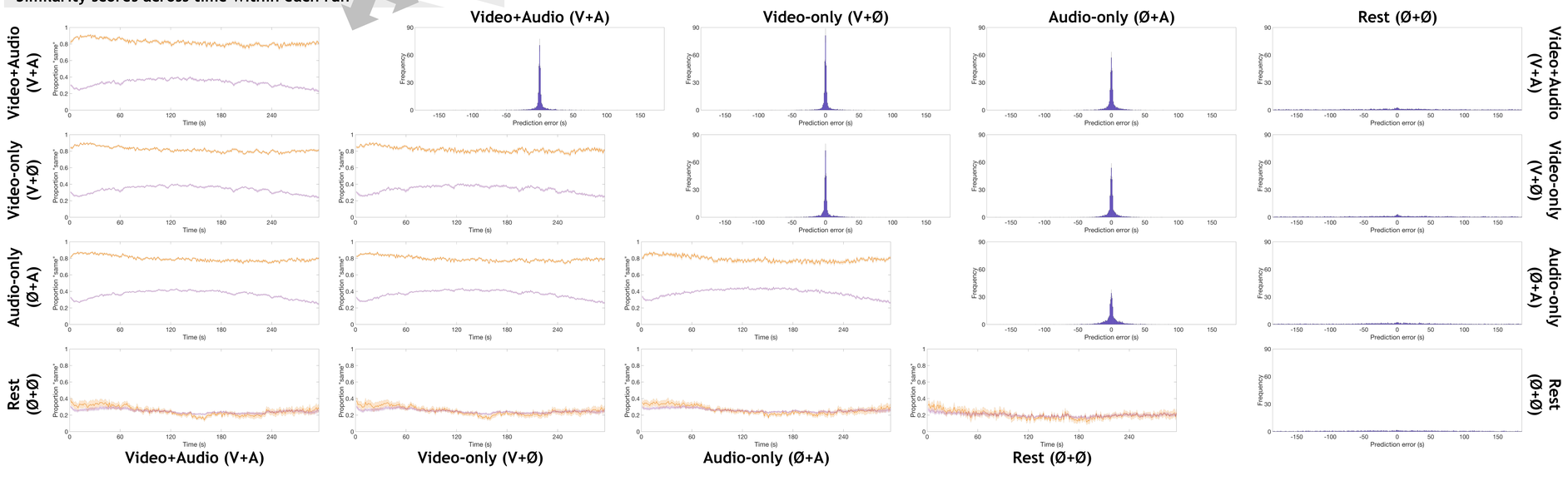
"Best guess" analysis for each timepoint

use highest scores in similarity matrices to generate "best guesses" of each voxel pattern's position in time; plot histograms of how far off those guesses were

orange: similarity scores between corresponding timepoints in runs

purple: similarity scores between a timepoint and all OTHER timepoints in another run

Similarity scores across time within each run



Receiver operating characteristic (ROC) curves

generated from scores contained in the similarity matrices, with a varying discrimination threshold; only on-diagonal value pairs (i.e., exact same timepoint in different runs) were considered "true" positives

Similarity values across a centered time window

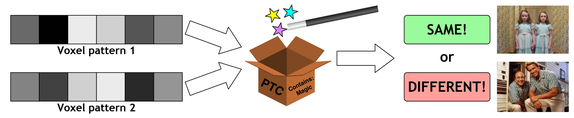
raw similarity scores from the deep learning classifier between all possible pairings of run types, and all possible pairings of the timepoints in each run

values from similarity matrices between each timepoint of one run and all timepoints in a ±30-second range of that point in another run

Similarity matrices across all timepoints

ANALYSIS METHODS

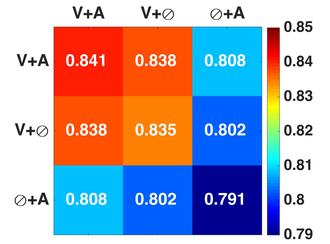
- Whole-brain multiband fMRI, 2.5mm isotropic voxels, TR=1000ms.
- Pre-processing: Motion correction and linear registration to MNI template. Template then warped into individual-subject space to create ROI masks of A1/V1 (via Harvard-Oxford atlas).
- Paired Trial Classification (PTC) analysis: Deep learning models (using DeLINEATE toolbox[2]) trained on fMRI patterns from 2 volumes (from different runs) at a time; classifier trained to distinguish if they represented the same timepoint in the film, or different timepoints.
- Simple network structure: One convolutional layer (single 2x10 filter), one 8-unit dense layer, and 2-unit output layer.



- Trained models were then applied to *ALL* possible fMRI volume pairs.

Overall same/different classification accuracy

proportion of accurate classifications of same/different time position based on pairs of voxel patterns drawn from different runs; all run pairings (from perception/imagery runs) classified at ~80% accuracy or better, even when the two runs did not share stimuli from the same sensory modality



CONCLUSIONS / FUTURE DIRECTIONS

- Volumes from all perception/memory runs could be classified with high accuracy and temporal precision, even runs that shared zero overlapping sensory stimuli.
- However, resting runs could not be classified, which is consistent with previous validation analyses demonstrating that performance was not due merely to nuisance factors like temporal drift.
- Future work will examine additional brain regions and determine whether classification performance changes over time.

REFERENCES / ACKNOWLEDGEMENTS

[1] Williams JM, Samal A, Rao PK, Johnson MR. 2019. Paired Trial Classification: A novel deep learning technique for MVPA. *Cognitive Neuroscience Society 26th Annual Meeting*, poster B102.

[2] Kuntzelman K, Williams JM, Samal A, Rao PK, Johnson MR. 2019. DeLINEATE: A deep learning toolbox for neuroimaging data analysis. Cognitive Neuroscience Society 26th Annual Meeting, poster B105. http://delineate.it.

Supported by NSF/EPSCoR #1632849 and NIH GM130461 to MRJ and colleagues.