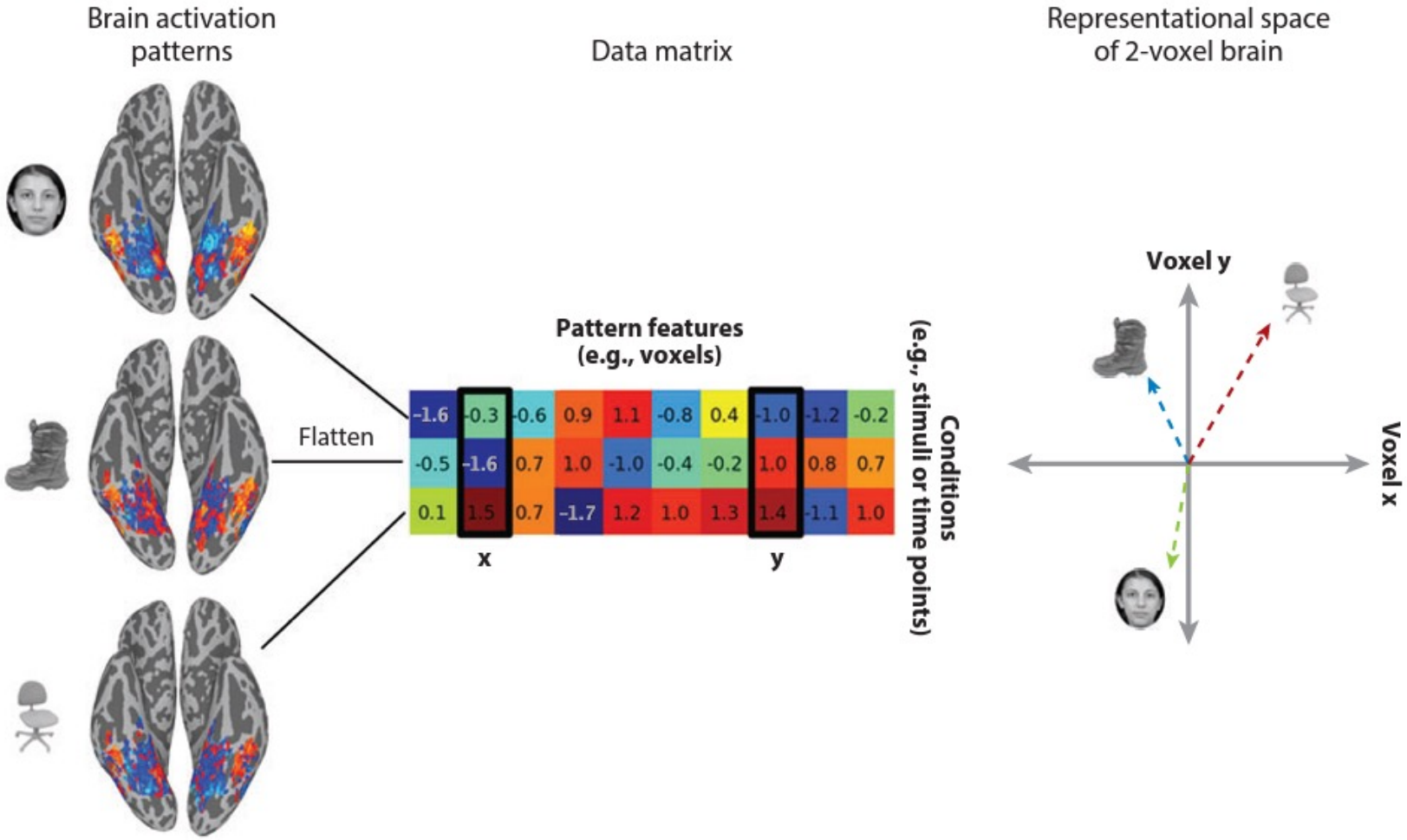
NSPDA project datasets

- We included several open access fMRI, EEG and single unit datasets.
- You are also encouraged to pick your own datasets, either open source datasets or data from your own research.
- We have included reference papers for each dataset, but you do not necessarily need to follow the exact papers. i.e. you can do neural decoding analysis from any dataset with stimulus labels.

Typical problems

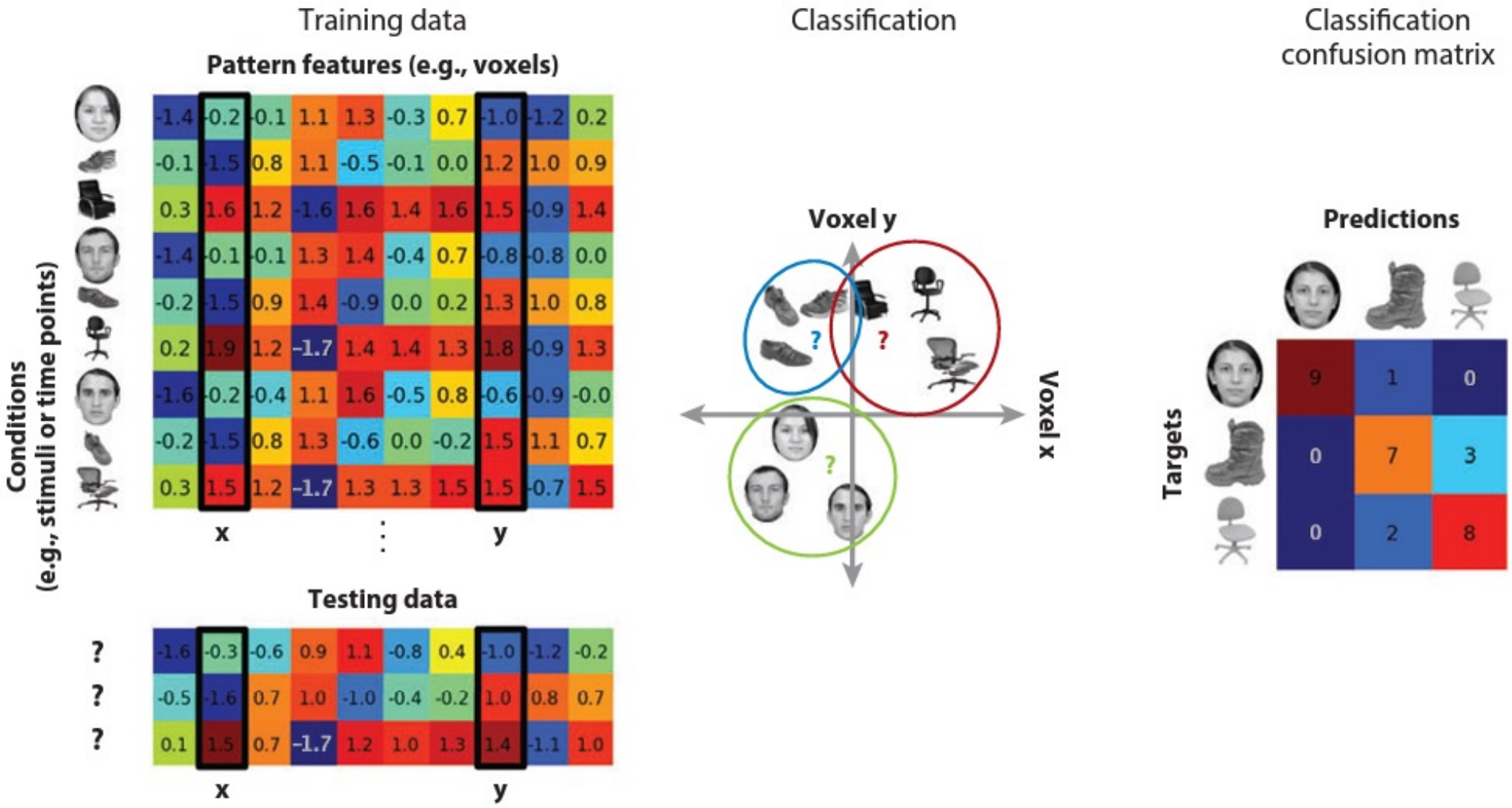
- Neural decoding:
  - Given observed neural activity patterns, how to determine the desired actions/perceived stimuli/…
  - Brain-computer interface
- Neural encoding:
  - Given a stimulus, predict the neural response

Examplar decoding methods: MVPA



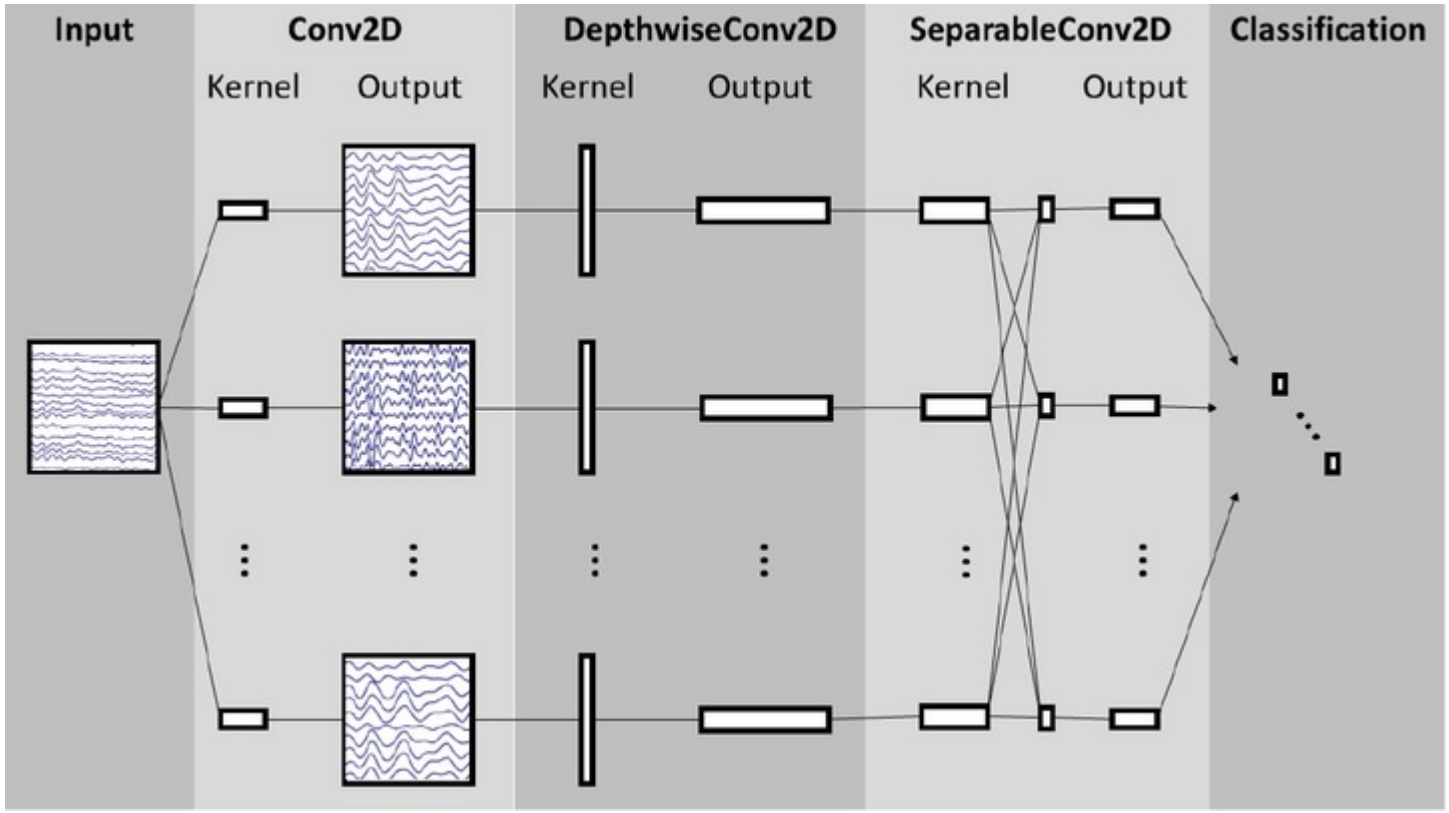
Haxby, J. V., Connolly, A. C., & Guntupalli, J. S. (2014). Decoding neural representational spaces using multivariate pattern analysis. *Annual review of neuroscience*, *37*, 435-456.

Examplar decoding methods: MVPA



Haxby, J. V., Connolly, A. C., & Guntupalli, J. S. (2014). Decoding neural representational spaces using multivariate pattern analysis. *Annual review of neuroscience*, *37*, 435-456.

Examplar decoding method: EEGNet



Lawhern, V. J., Solon, A. J., Waytowich, N. R., Gordon, S. M., Hung, C. P., & Lance, B. J. (2018). EEGNet: a compact convolutional neural network for EEG-based brain–computer interfaces. *Journal of neural engineering*, *15*(5), 056013.

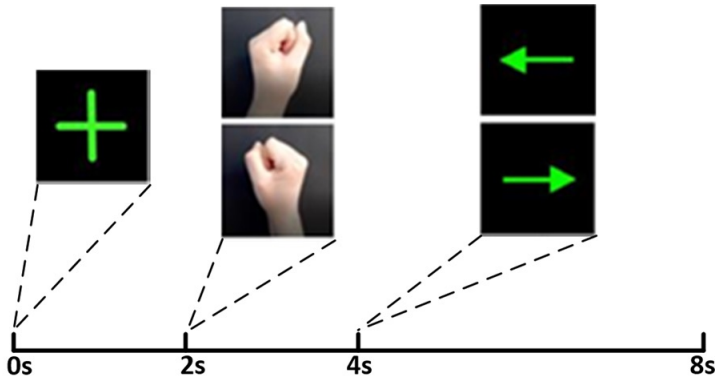
Datasets

Task paradigms	Dataset	En/Decoding	Data type
Motor imagery	Shu_dataset	decoding	EEG
Motion imagery	SEED-IV	decoding	EEG
Attempted speech	Speech BCI	decoding	Single unit
Prosthetic cursor	BCI 2006	decoding	Single unit
Object recognition	Marques2020	encoding	Single unit

Shu dataset 2021

a

b



Experimental procedure	Required time (min)	Cumulative time (min)
Fill in the questionnaire	5	5
Wear acquisition EEG equipment	25	30
Debug the signal	5	35
Motor imagery Experiment	35	70
Verify data	2	72

The dataset includes 5 session data from 5 different days (2–3 days apart) for 25 subjects.

Each session contains 100 trials of left-hand and right-hand MI.

One trial consists of three parts: (1) fixation (2) cues (3) imagining movements

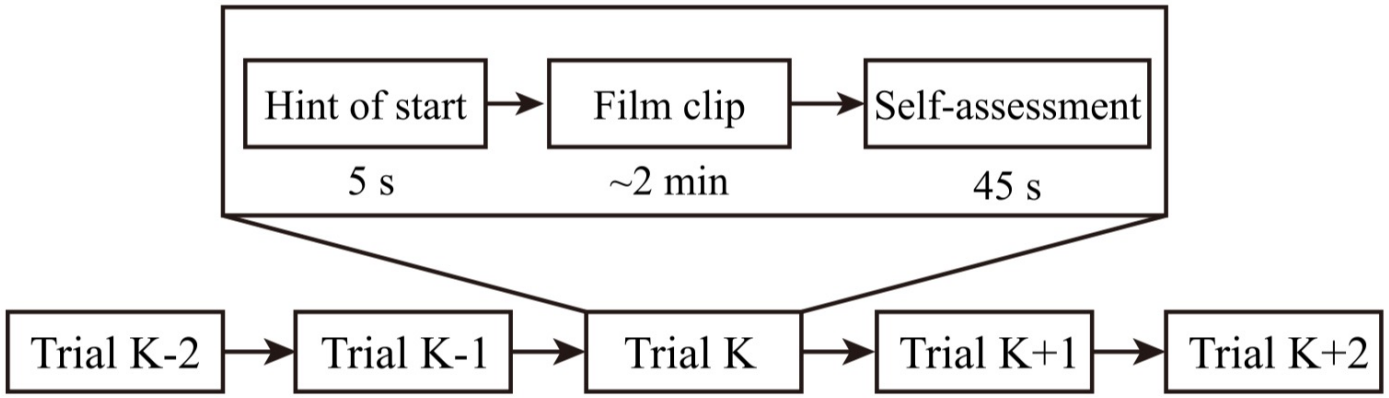
Ma, J., Yang, B., Qiu, W. *et al.* A large EEG dataset for studying cross-session variability in motor imagery brain-computer interface. *Sci Data* **9**, 531 (2022). https://doi.org/10.1038/s41597-022-01647-1

Shu dataset 2021: classification

- With-in session classification
  - all trials of each session were randomly divided into the training set, verification set, and test set respectively according to the proportion of 8:1:1.
- Cross-session classification
  - the data in the first session was used as the training set, and the data in the remaining four sessions of the same subject were used as the test set.
- Cross-session adaptation
  - one subject was selected as the target domain, and the rest of the subjects were selected as the source domain. The source domain was divided into a training set and a validation set. Randomly selected three subjects as the validation set and the rest as the training set

Ma, J., Yang, B., Qiu, W. *et al.* A large EEG dataset for studying cross-session variability in motor imagery brain-computer interface. *Sci Data* **9**, 531 (2022). https://doi.org/10.1038/s41597-022-01647-1

SEED-IV



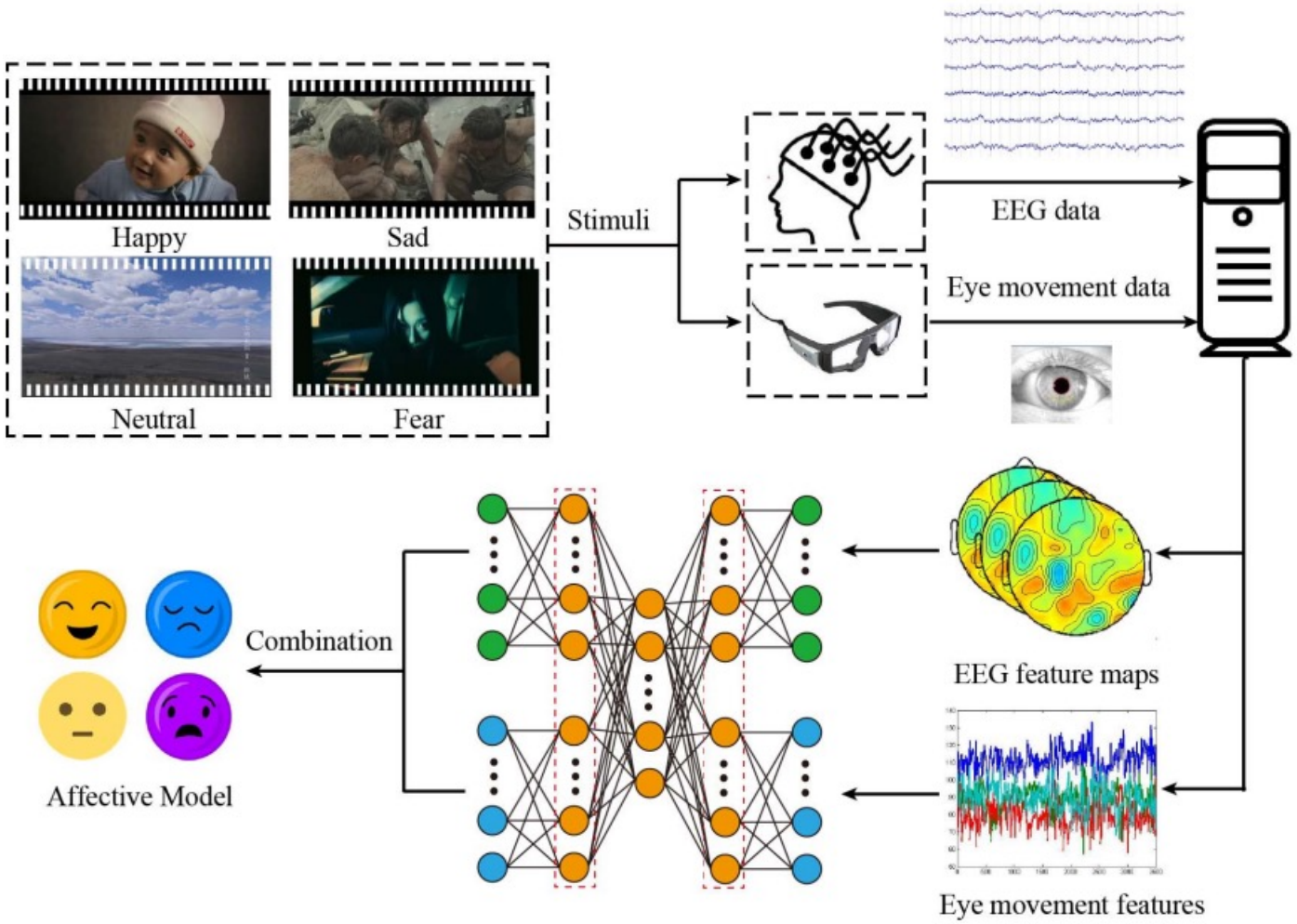
A total of 15 subjects participated in the experiment.

For each participant, 3 sessions were performed on different days

Each session contained 24 trials.

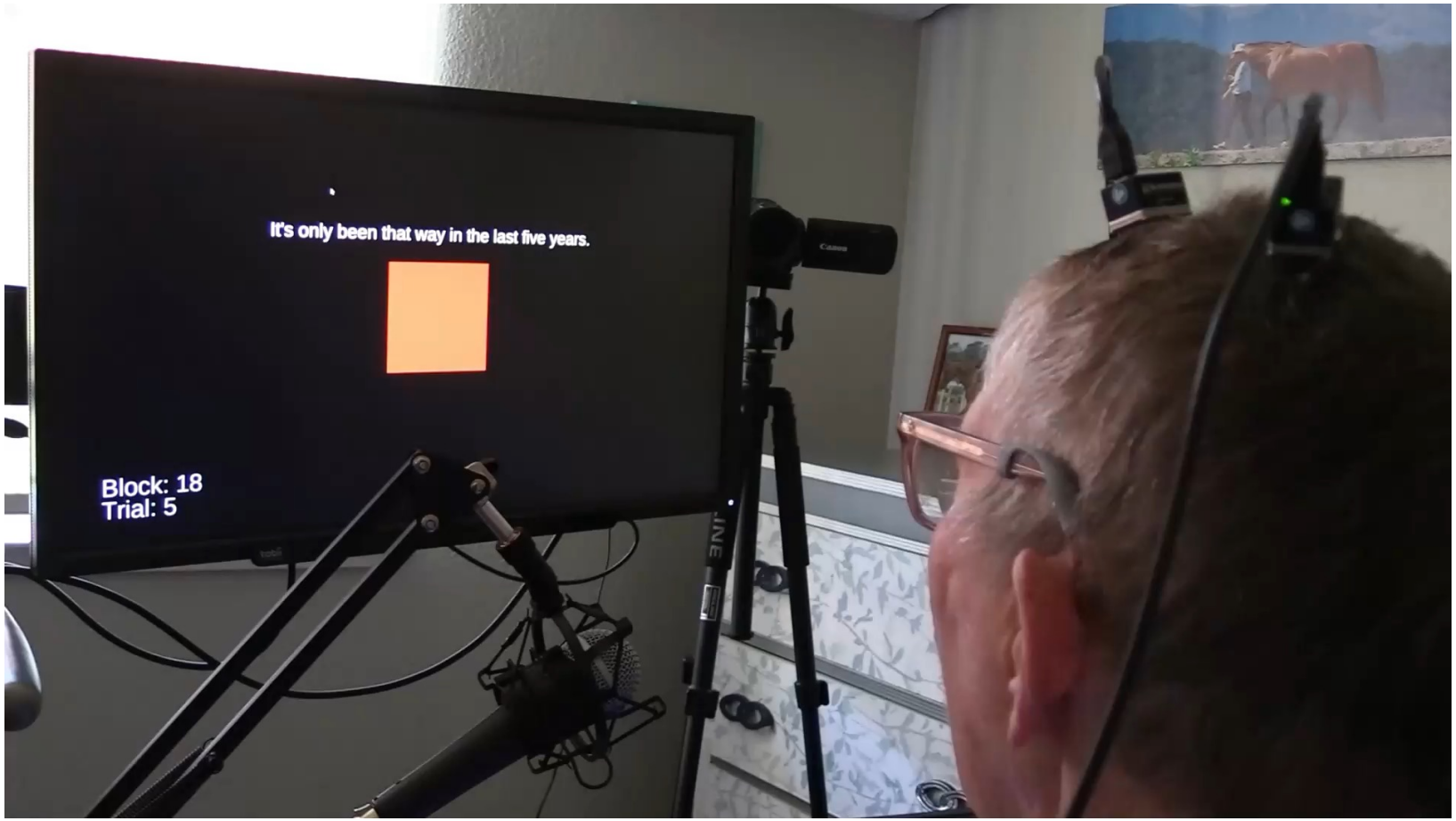
W. -L. Zheng, W. Liu, Y. Lu, B. -L. Lu and A. Cichocki, "EmotionMeter: A Multimodal Framework for Recognizing Human Emotions," in *IEEE Transactions on Cybernetics*, vol. 49, no. 3, pp. 1110-1122, March 2019, doi: 10.1109/TCYB.2018.2797176.

SEED-IV : classification



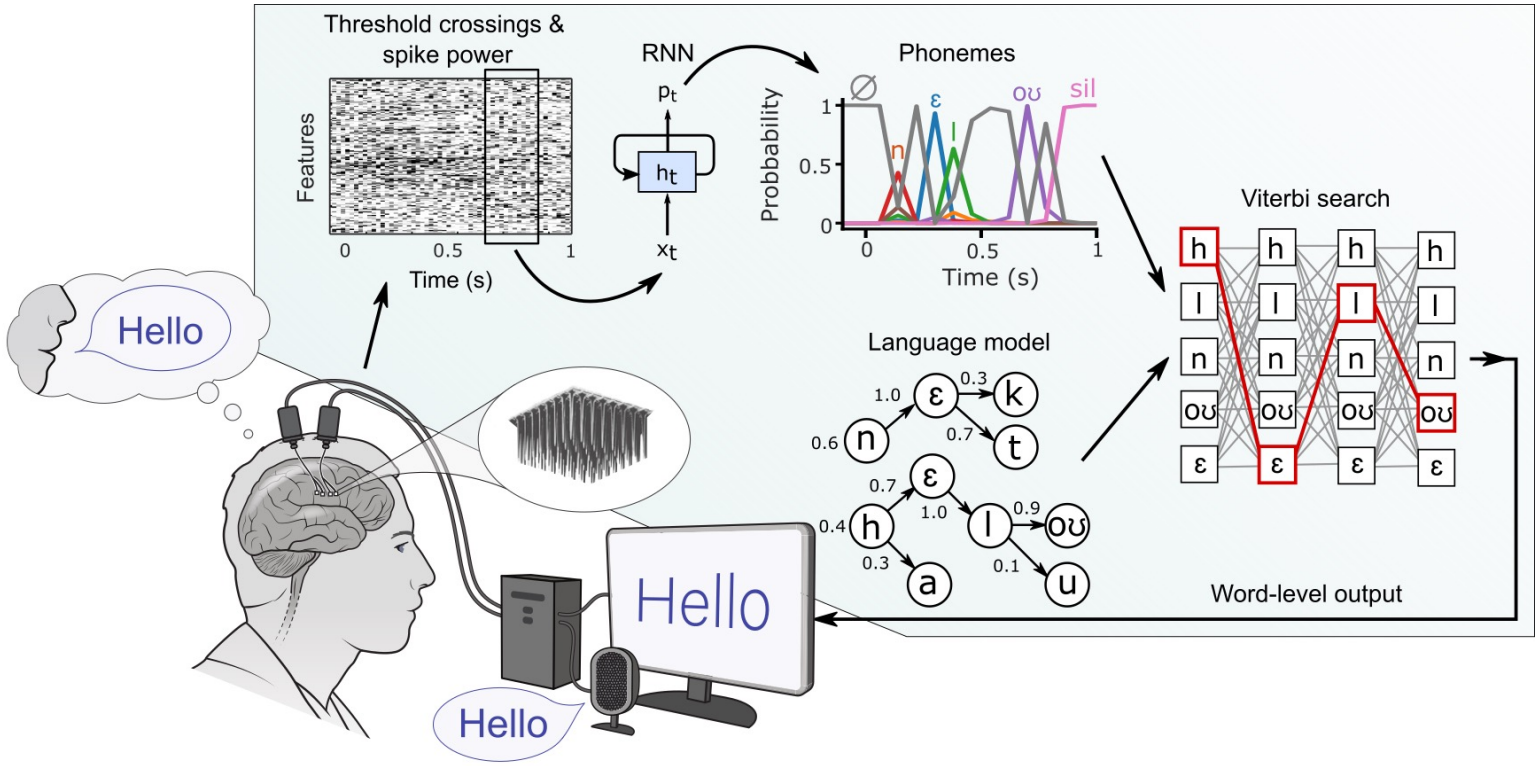
W. -L. Zheng, W. Liu, Y. Lu, B. -L. Lu and A. Cichocki, "EmotionMeter: A Multimodal Framework for Recognizing Human Emotions," in *IEEE Transactions on Cybernetics*, vol. 49, no. 3, pp. 1110-1122, March 2019, doi: 10.1109/TCYB.2018.2797176.

Speech BCI



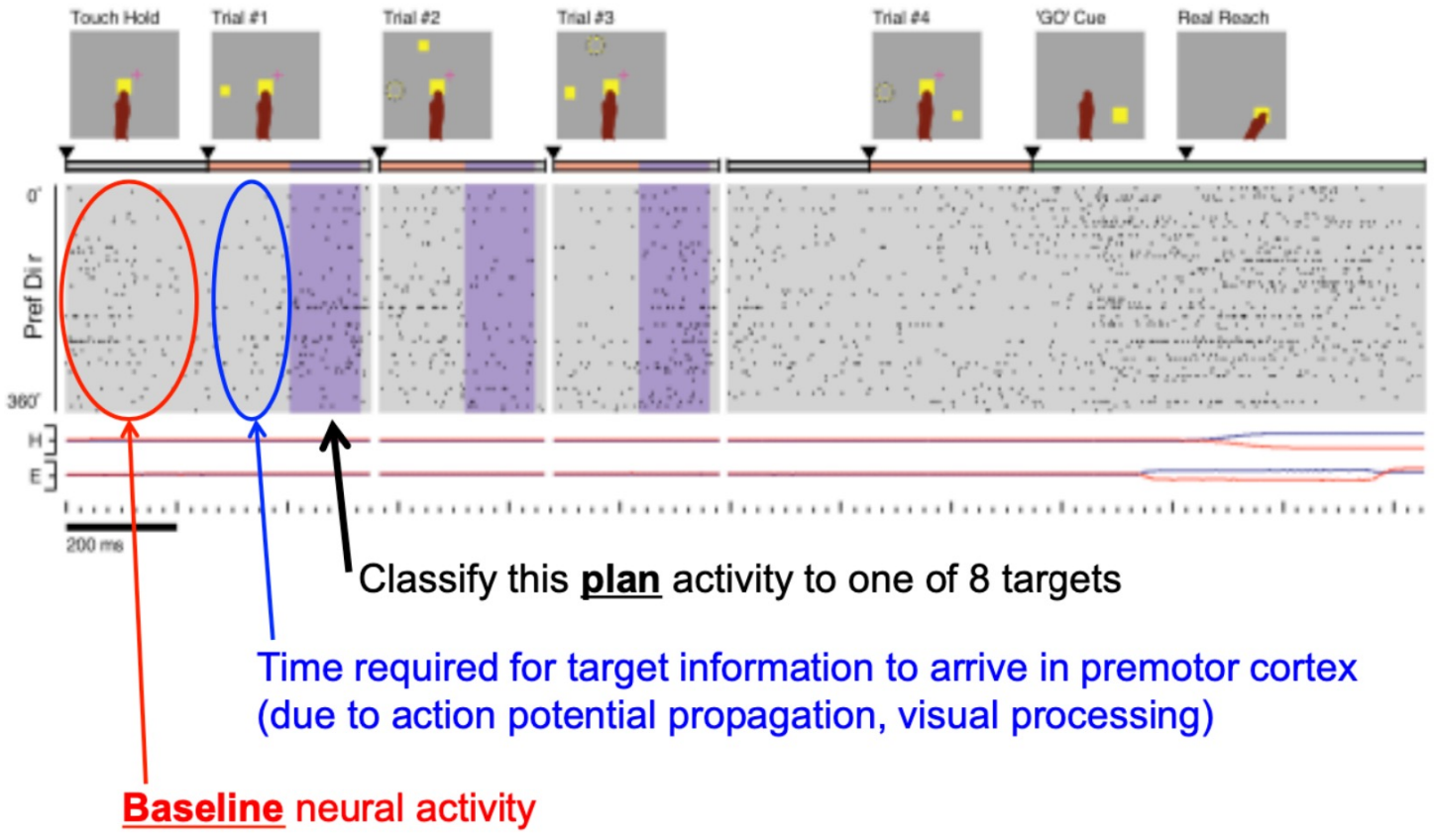
Willett, F.R., Kunz, E.M., Fan, C. et al. A high-performance speech neuroprosthesis. Nature 620, 1031–1036 (2023). https://doi.org/10.1038/s41586-023-06377-x

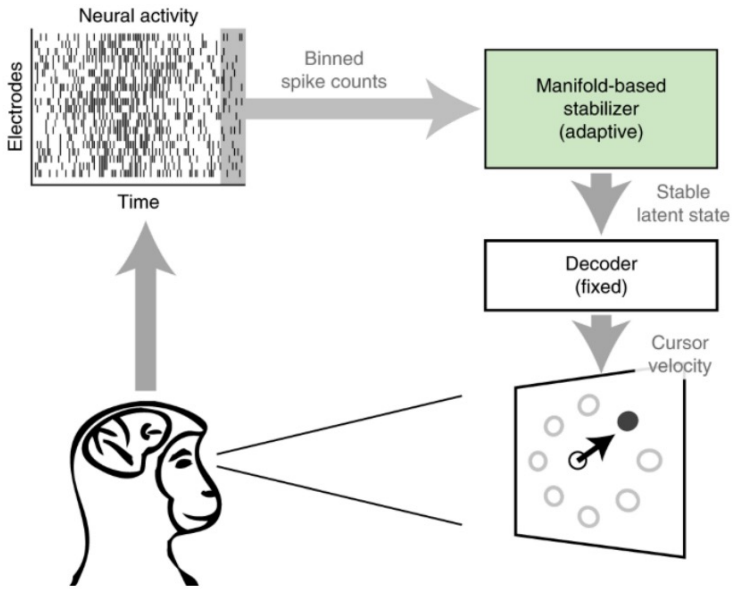
Speech BCI : Phonemes & words decoding



Willett, F.R., Kunz, E.M., Fan, C. et al. A high-performance speech neuroprosthesis. Nature 620, 1031–1036 (2023). https://doi.org/10.1038/s41586-023-06377-x

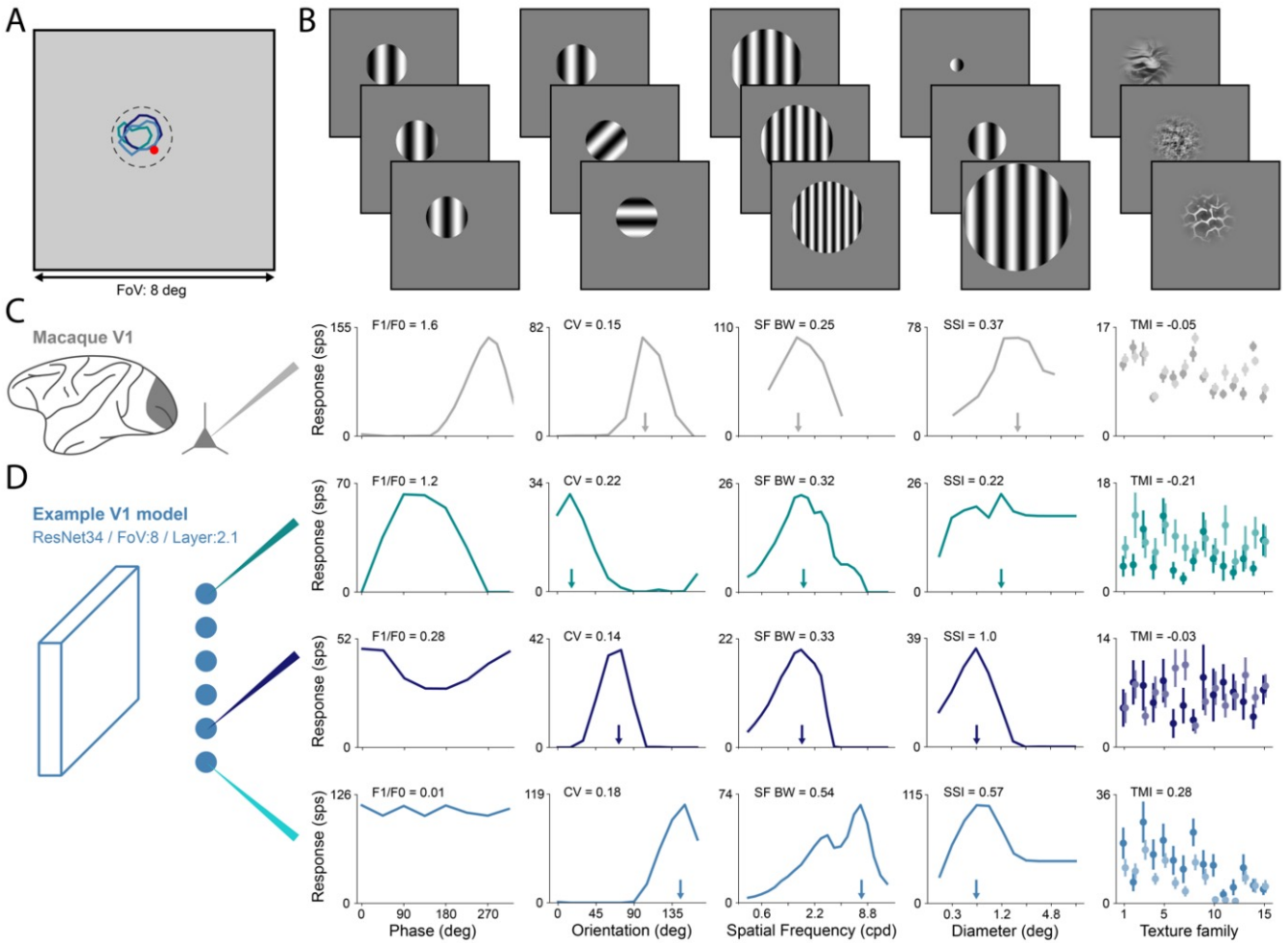
BCI 2006





Santhanam, G., Ryu, S. I., Yu, B. M., Afshar, A., & Shenoy, K. V. (2006). A high-performance brain-computer interface. Nature, 442(7099), 195–198.
https://doi.org/10.1038/nature04968

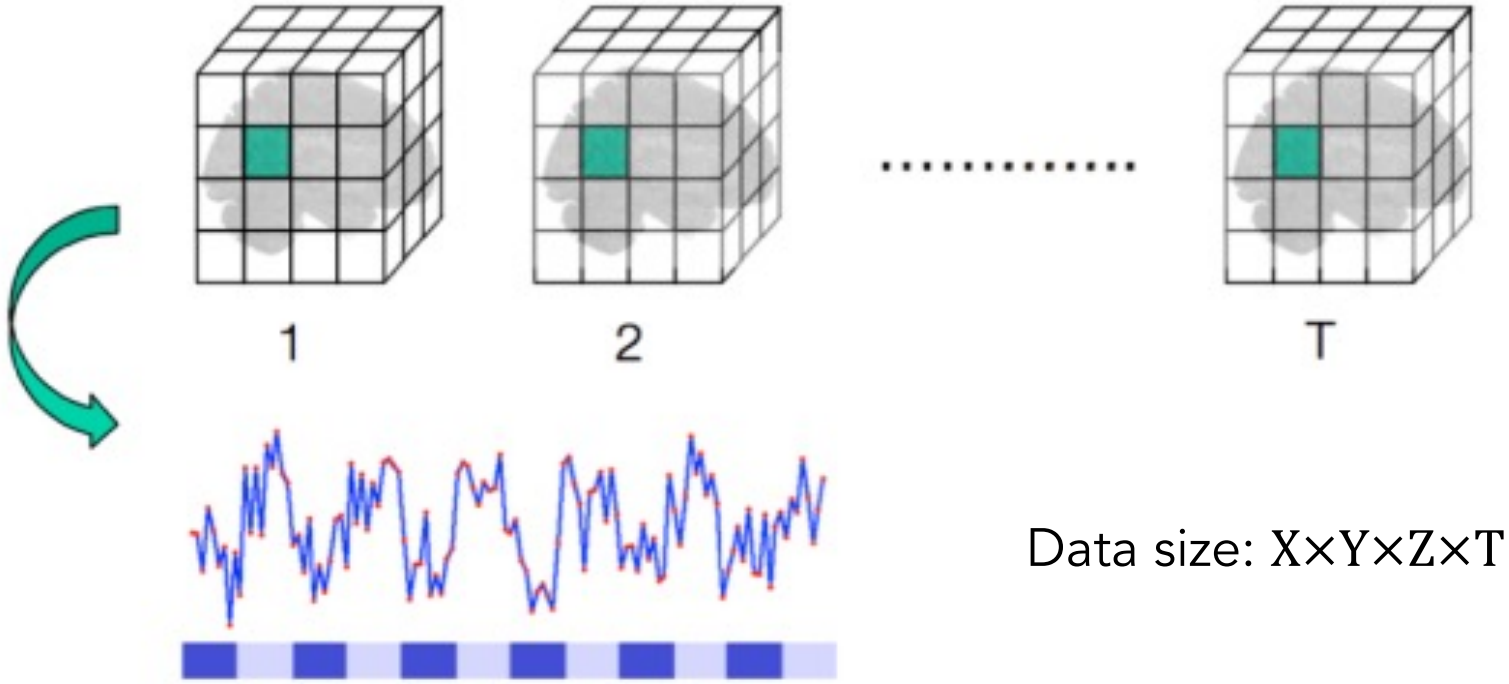
Marques2020



Property	# neurons	# bins	Scale
Preferred orientation	385	4	Linear
Circular variance	308	13	Linear
Orientation selective	308	2	Binary
Orientation half-bandwidth	308	9	Linear
Orthogonal / Preferred ratio	308	13	Linear
CV / Half-bandwidth	308	15	Log.
(Orth./Pref.) - CV	308	19	Linear
Peak Spatial Frequency	363	12	Log.
SF Selective	87	2	Binary
SF Bandwidth	87 (73)	10	Linear
Grating Summation Field	190 (148)	8	Log.
Surround Diameter	190 (148)	8	Log.
Surround Suppression Index	190	10	Linear
Texture Modulation Index	102	24	Linear
Absolute Texture Modulation Index	102	12	Linear
F1/F0 ratio	308	10	Linear
Texture Selectivity	102	10	Linear
Texture Sparseness	102	10	Linear
Texture Variance Ratio	102	12	Log.
Max DC Response	308	9	Log.
Max Texture Response	102	12	Log.
Max Noise Response	102	12	Log.

Multi-scale hierarchical neural network models that bridge from single neurons in the primate primary visual cortex to object recognition
Tiago Marques, Martin Schrimpf, James J. DiCarlo
bioRxiv 2021.03.01.433495; doi: https://doi.org/10.1101/2021.03.01.433495

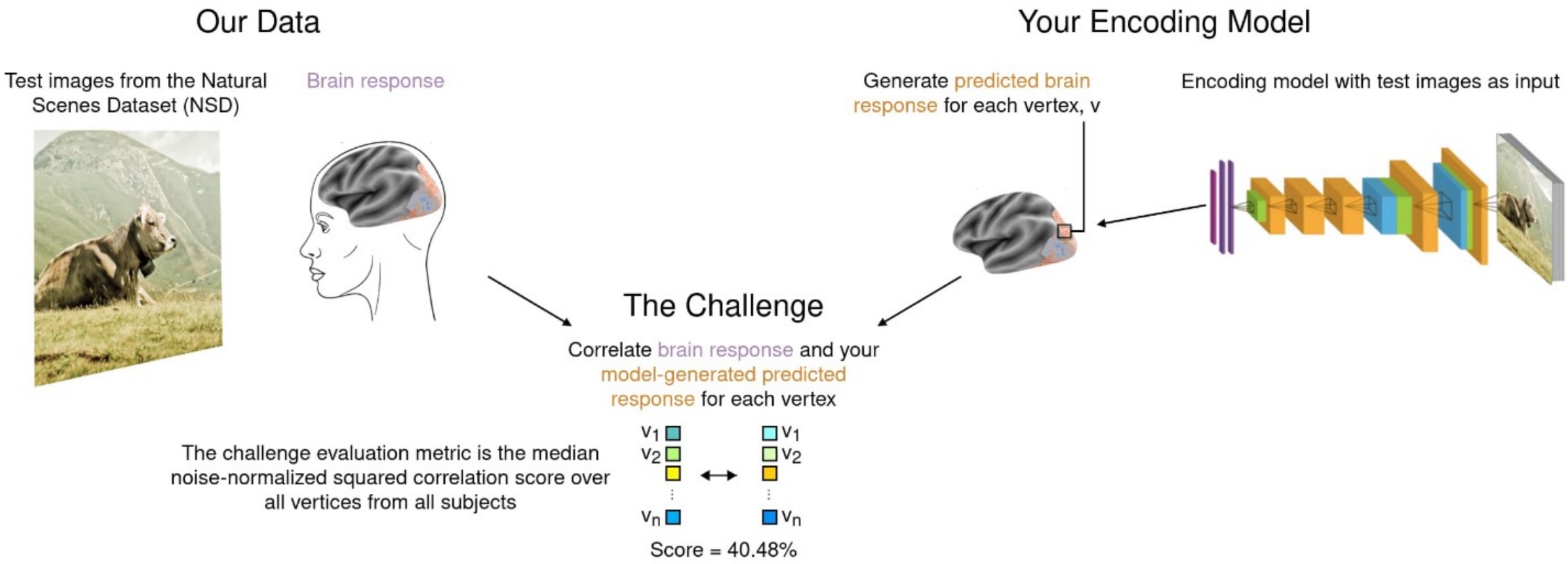
fMRI



Data size: X×Y×Z×T

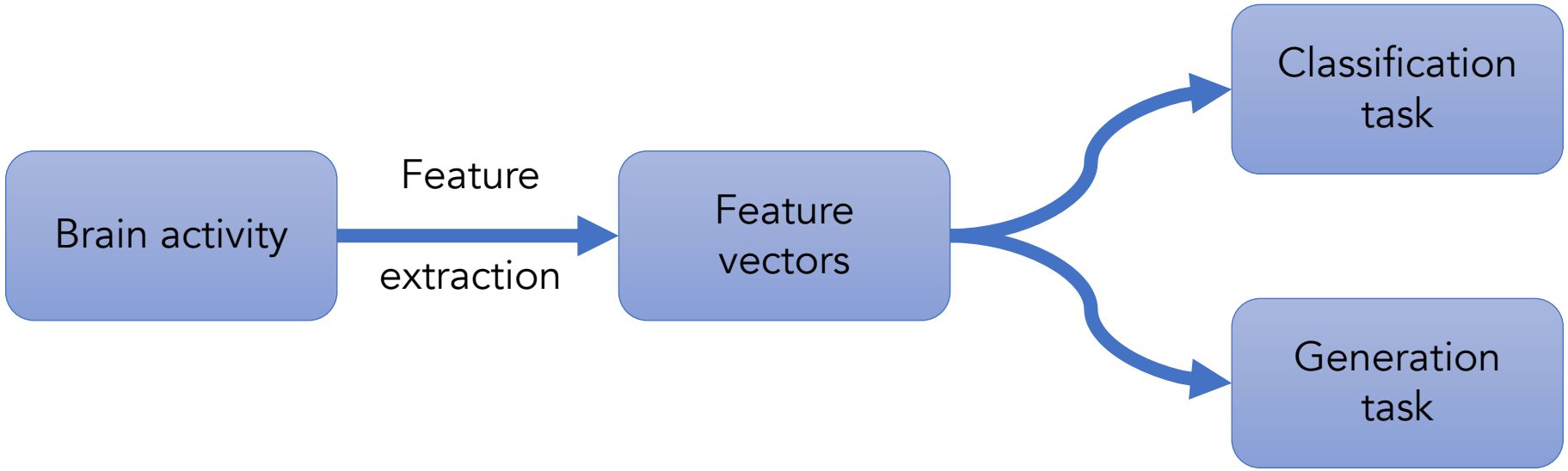
Encoding task

- Use stimulus to predict brain activity

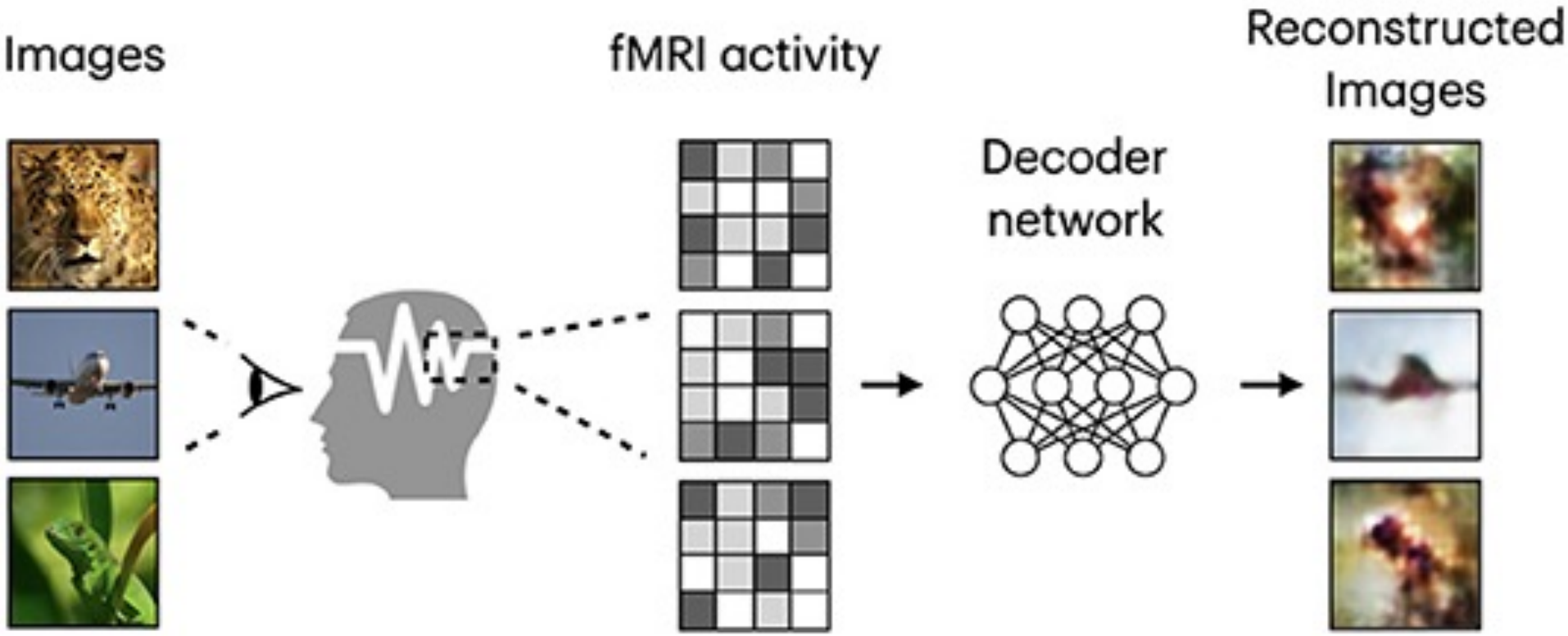


Decoding task

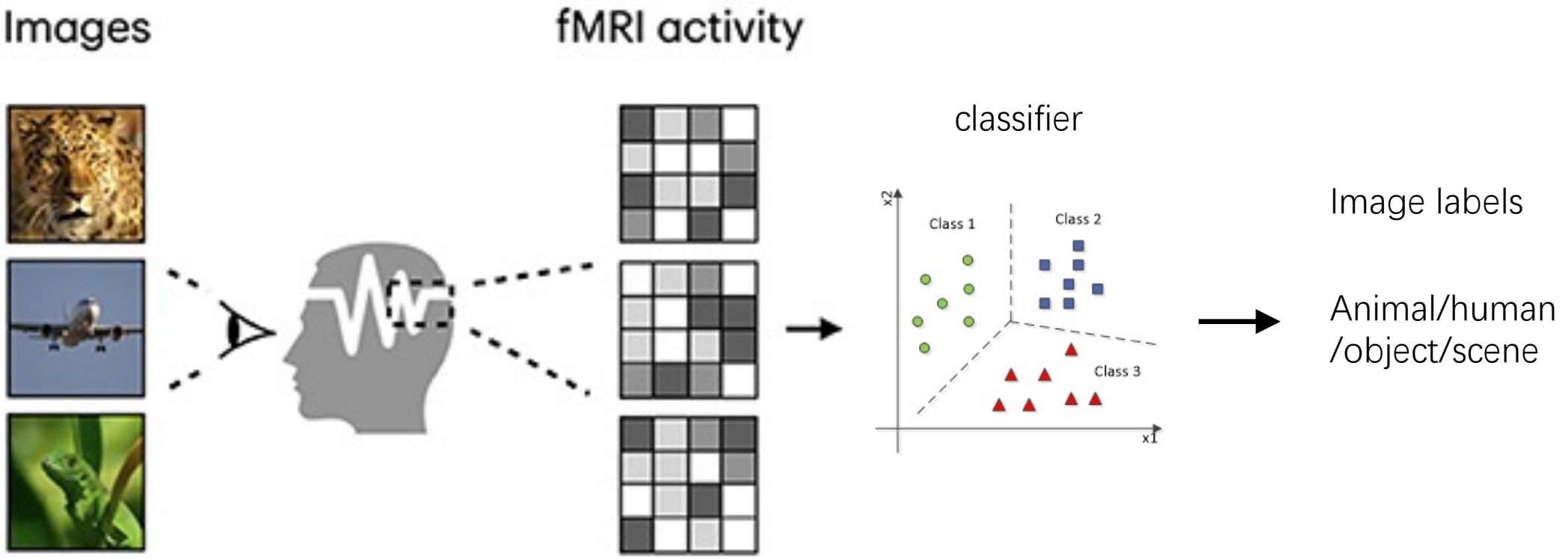
1. Use brain activity to decode the category of image. (Classification)
2. Use brain activity to identify the image or sentence. (Classification)
3. Use brain activity to reconstruct the image or language. (Generation)



Decoding example



Decoding example



Datasets

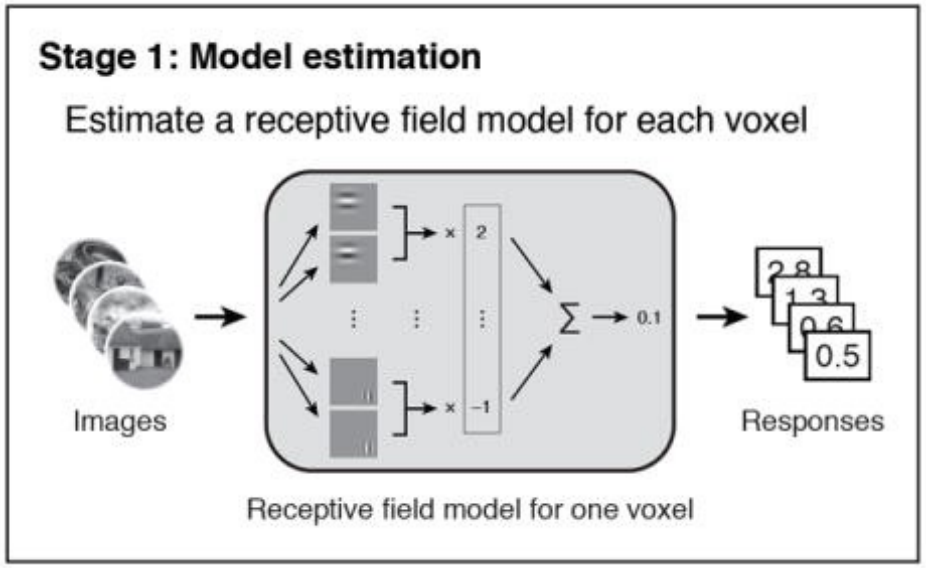
- Visual stimulus
  - Vim-1 – 1 decoding project
  - Natural Scene Dataset (NSD) – 1 encoding & 2 decoding projects
  - BOLD 5000 – 1 decoding project
- Speech stimulus
  - Natural language dataset – 1 encoding & 1 decoding project

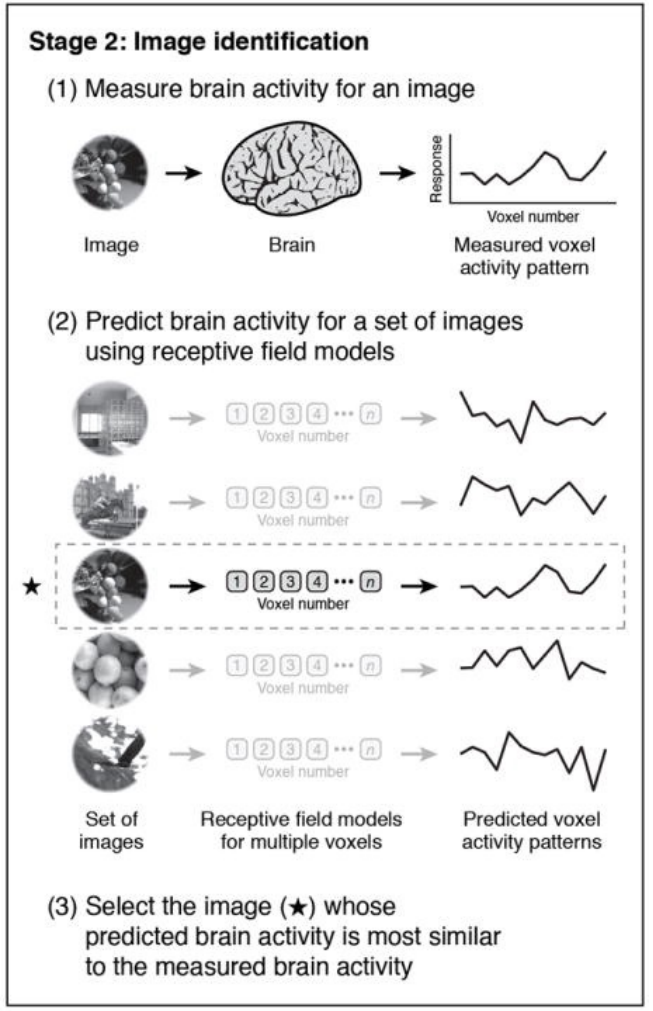
Vim-1

- Stimulus: simple visual stimulus (gratings) or images from several fixed categories
- Subjects: 2 (70 runs in total)
- Data:
  - T1
  - fMRI (Stimulus)
  - ROI (V1, V2, V3, V3A, V3B, V4, LatOcc)

Kay, K.N.; Naselaris, T.; Gallant, J. (2011): fMRI of human visual areas in response to natural images. CRCNS.org. http://dx.doi.org/10.6080/K0QN64NG

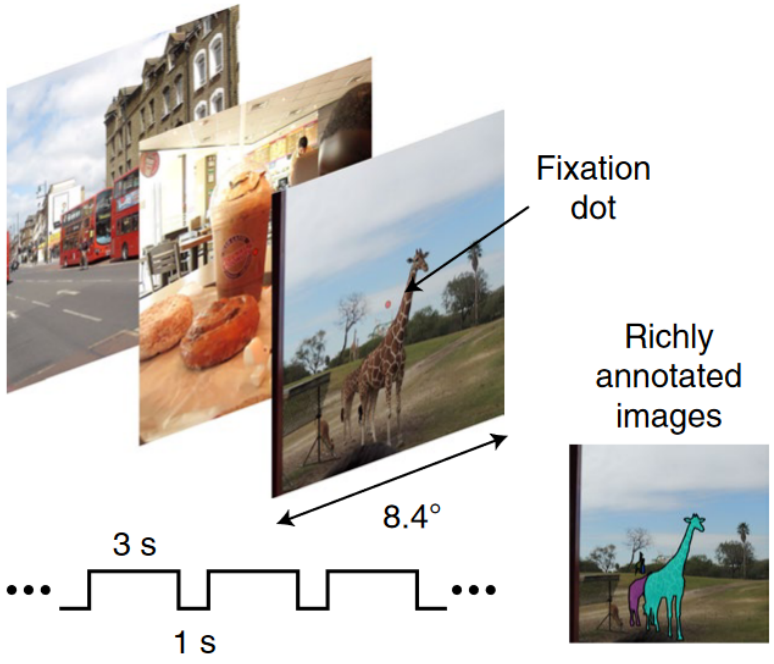
Vim-1 – Decoding example



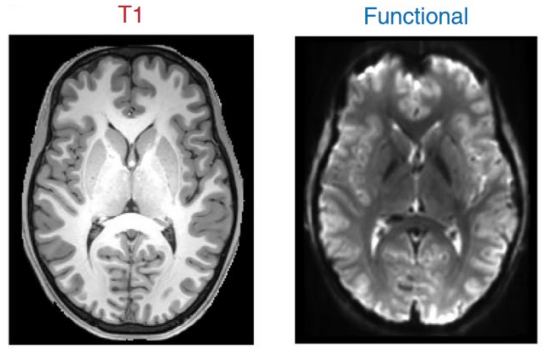


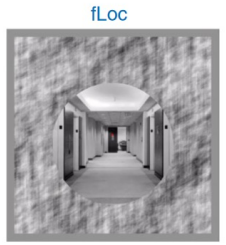
Kay, Kendrick N., et al. "Identifying natural images from human brain activity." Nature 452.7185 (2008): 352-355.

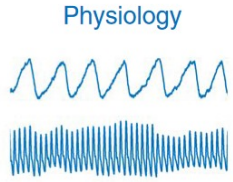
Natural Scene Dataset (NSD)



- Stimulus: natural scenes from COCO
- Subjects: 8
- Data:
  - T1
  - fMRI (pRF, fLoc, Stimulus)
  - Behavior
  - Physiology
  - Eye-tracking

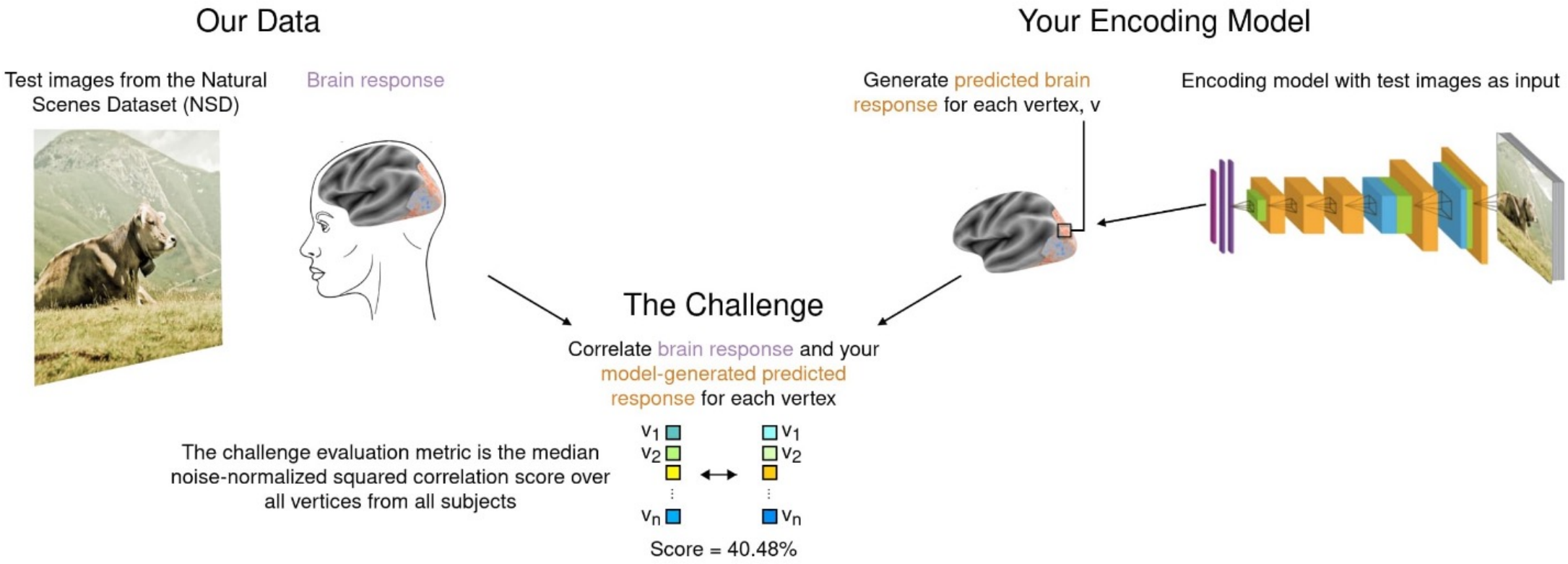






Allen, Emily J., et al. "A massive 7T fMRI dataset to bridge cognitive neuroscience and artificial intelligence." *Nature neuroscience* 25.1 (2022): 116-126.

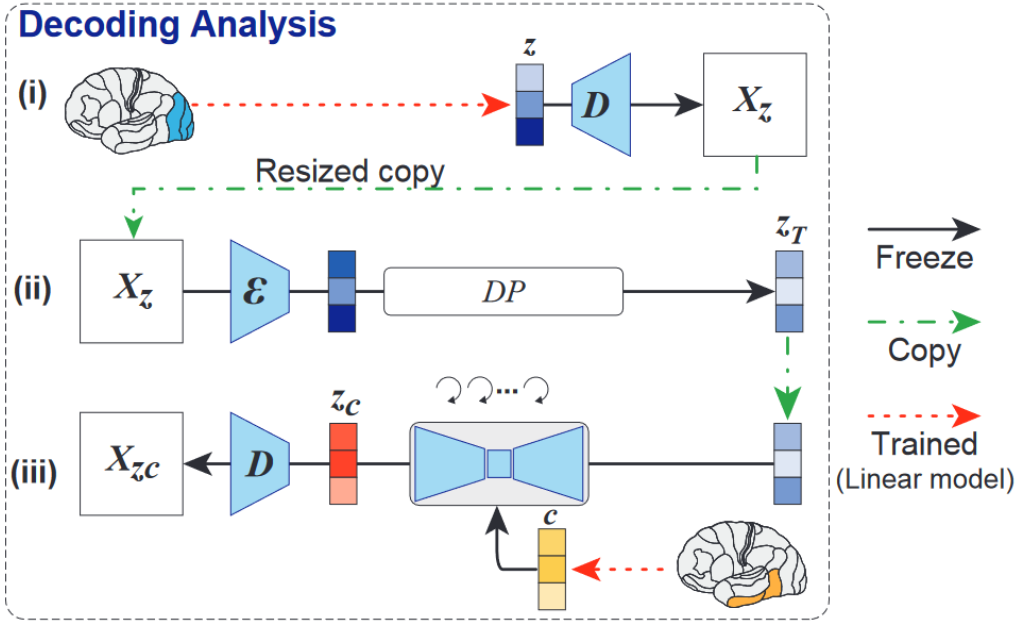
NSD – Encoding example



Gifford, Alessandro T., et al. "The algonauts project 2023 challenge: How the human brain makes sense of natural scenes." arXiv preprint arXiv:2301.03198 (2023).

NSD – Decoding example

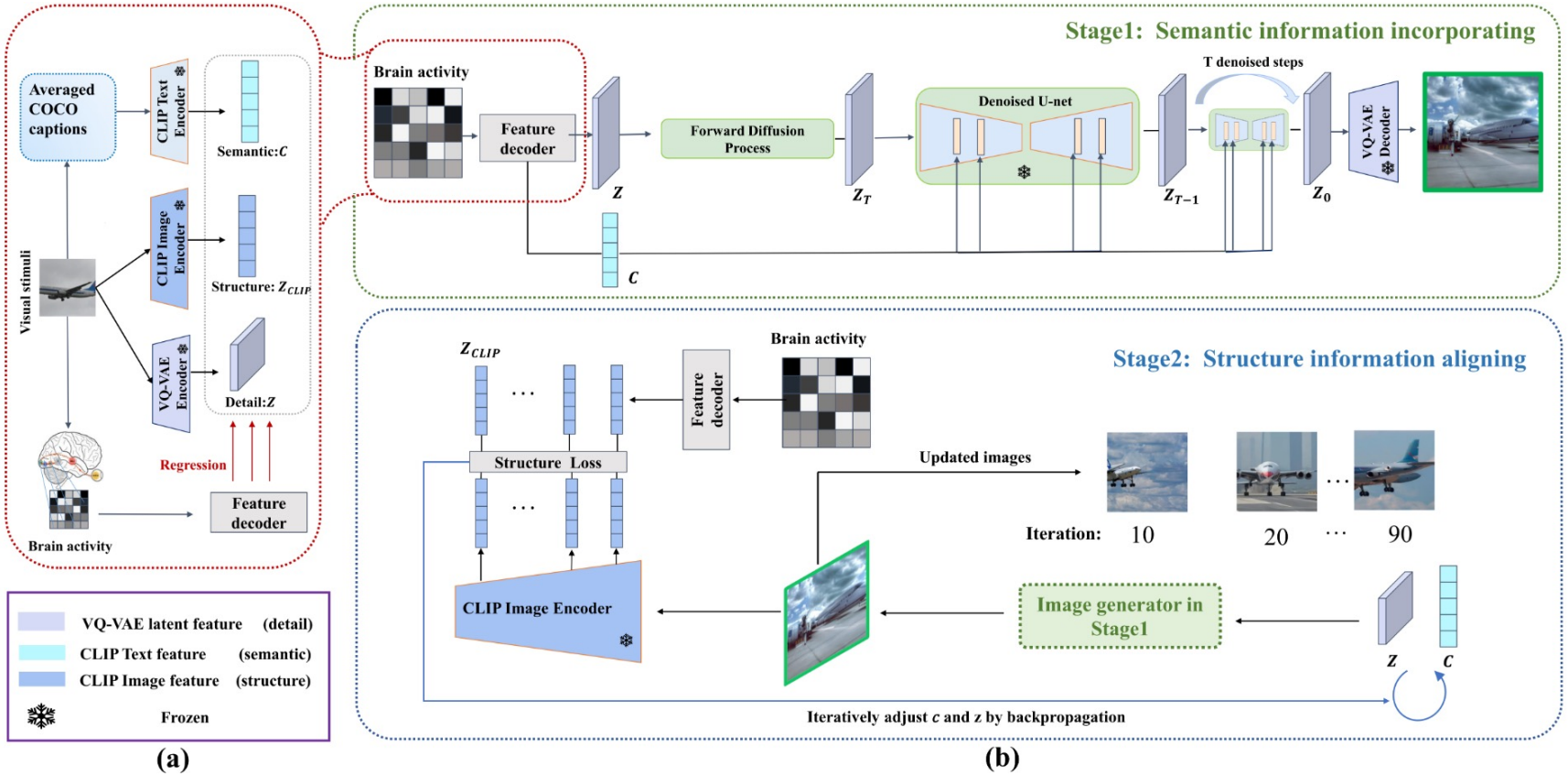
Autoencoder + Stable Diffusion + Linear model



Takagi, Yu, and Shinji Nishimoto. "High-resolution image reconstruction with latent diffusion models from human brain activity." CVPR. 2023.

NSD – Decoding example

CLIP + Autoencoder + Stable Diffusion + Structure alignment loss



Lu, Yizhuo, et al. "MindDiffuser: Controlled Image Reconstruction from Human Brain Activity with Semantic and Structural Diffusion." arXiv preprint arXiv:2303.14139 (2023).

BOLD 5000

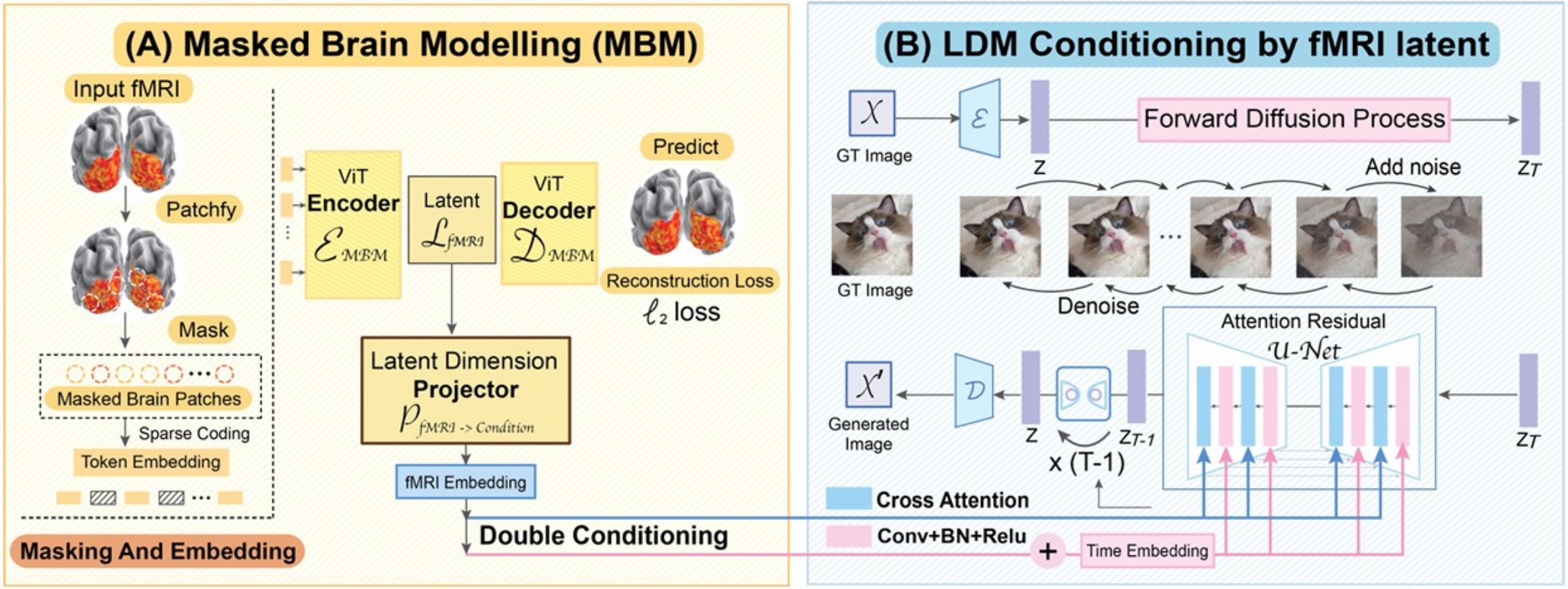
- Stimulus: 1000 scenes, 2000 COCO images, 1916 ImageNet images
- Subjects: 4
- Data:
  - T1
  - fMRI (fLoc, Stimulus)
  - ROI mask
  - GLM-denoised fMRI

Participants	4
fMRI Sessions per Participants	16
Total fMRI Scene Runs Per Participant	142
Total Functional Localizer Runs Per Participant	8
Total Scene Trials Per Participant	5,254
Unique Scene Stimuli Per Participant	4,916

Chang, Nadine, et al. "BOLD5000, a public fMRI dataset while viewing 5000 visual images." Scientific data 6.1 (2019): 49.

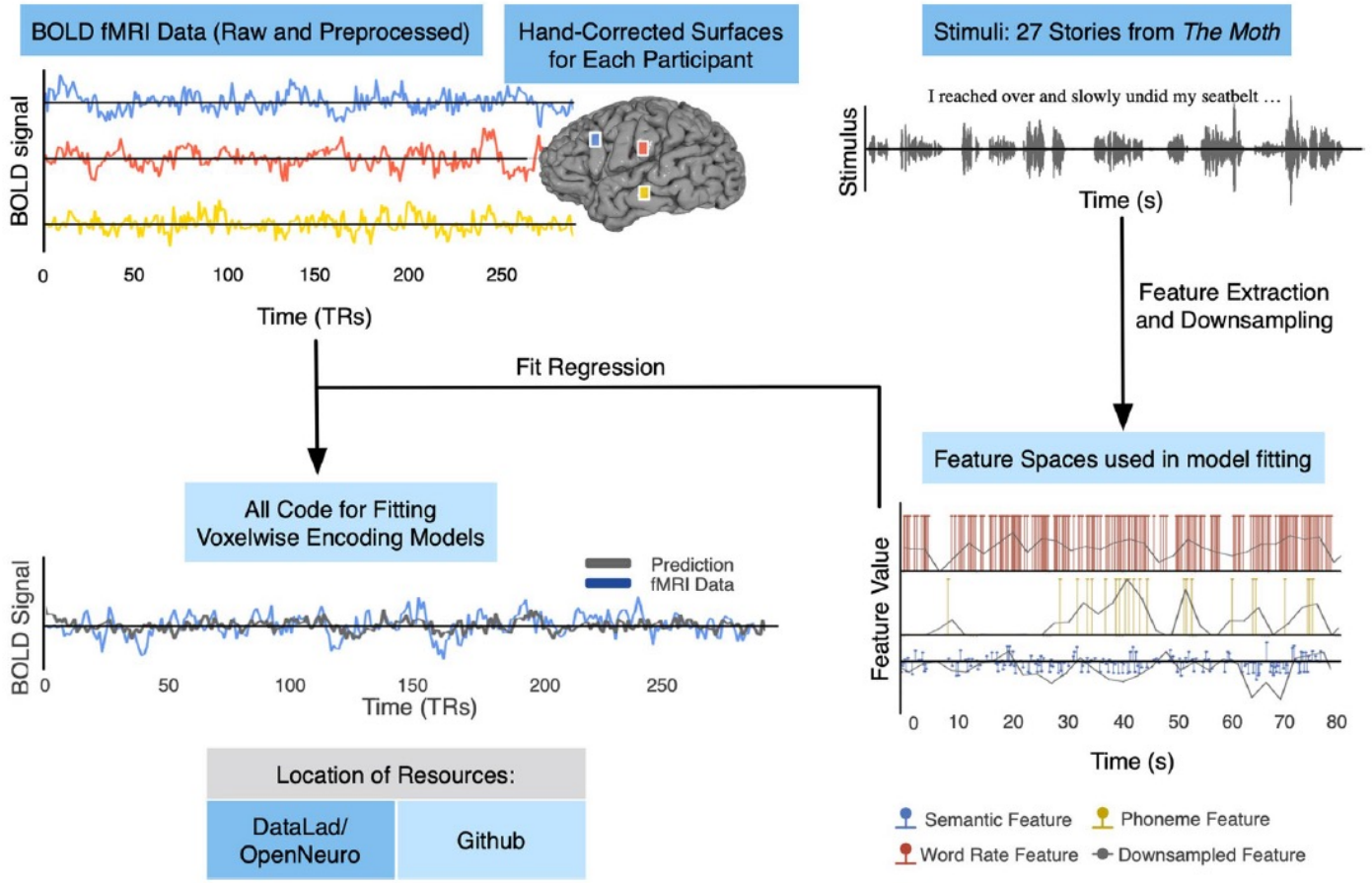
BOLD 5000 – Decoding example

Finetune Pre-training model + Latent Diffusion Model



Chen, Z., et al. "Seeing beyond the brain: Masked modeling conditioned diffusion model for human vision decoding." arXiv, November (2022).

Natural language dataset – Encoding example

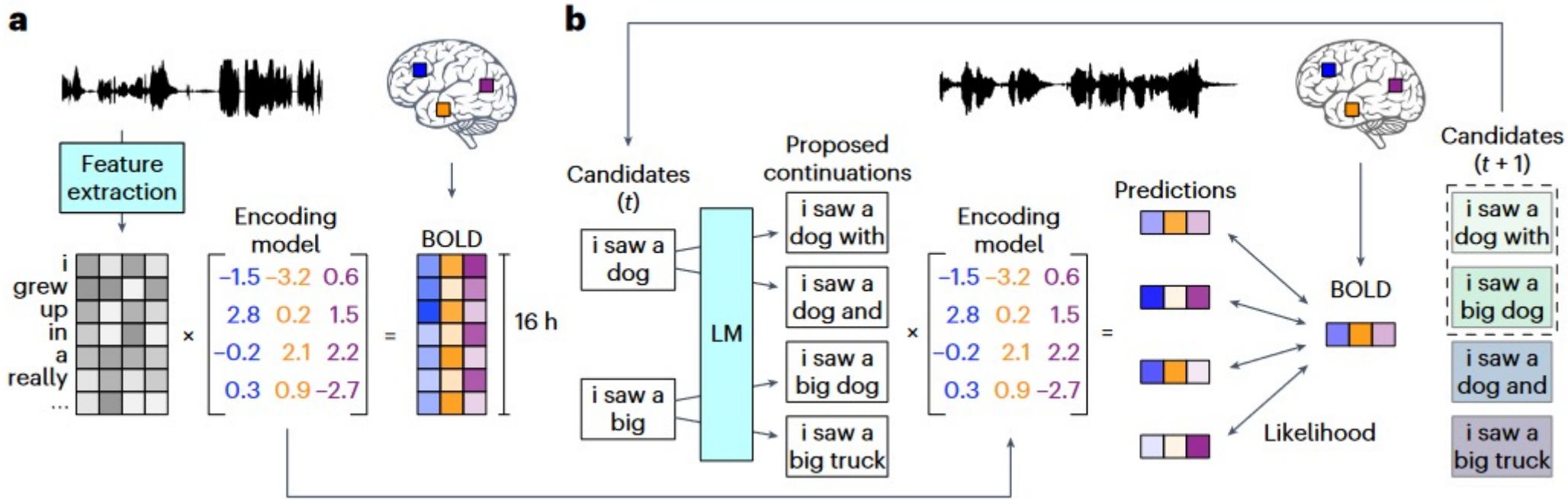


- Stimulus: 27 narrative stories
- Subjects: 8
- Data:
  - T1
  - fMRI (fLoc, Stimulus)
  - Semantic feature
  - Phoneme feature
  - Word rate feature

LeBel, Amanda, et al. "A natural language fMRI dataset for voxelwise encoding models." Scientific Data 10.1 (2023): 555.

Natural language dataset – Decoding example

Encoding model (Linear) + GPT-1 + Beam search decoder



Tang, Jerry, et al. "Semantic reconstruction of continuous language from non-invasive brain recordings." Nature Neuroscience (2023): 1-9.