Implementing Linear Decoders with fMRI Data

BIPN 162 NEURAL DATA SCIENCE

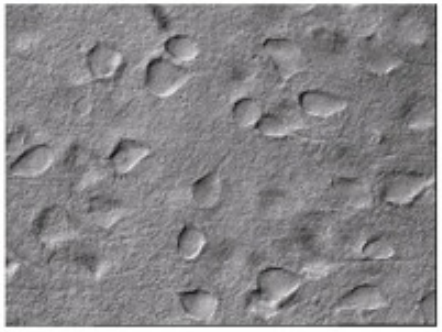
Lecture Overview

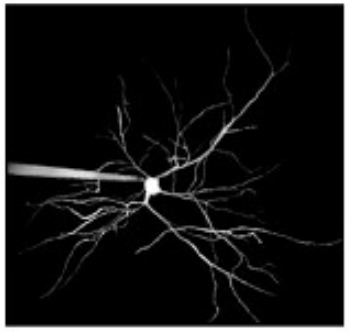
- fMRI basics - introduction to the physics and physiology of fMRI
- fMRI data collection and formatting
- Introduction to the experiment, research question and dataset
- Hands-on programming tasks to analyze the fMRI dataset and answer scientific questions
  - Task 1: *brain image visualization*
  - Task 2: *extract visually responsive voxels using anova*
  - Task 3: *predict stimulus location using linear regression*
  - Task 4: *visualise neural representations of stimulus location using MDS*

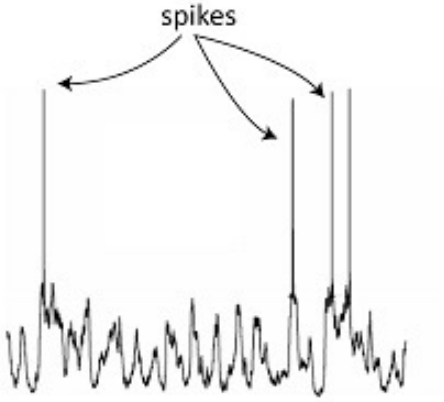
Learning Objectives

- Describe the fundamentals of fMRI, including its underlying mechanism, constraints and data formats
- Apply programming skills to visualisation of 4D data and implementing more complex analyses
- Implement ANOVA and linear regression to solve real-life research questions

Prelude – neural correlates of cognition and complex behavior



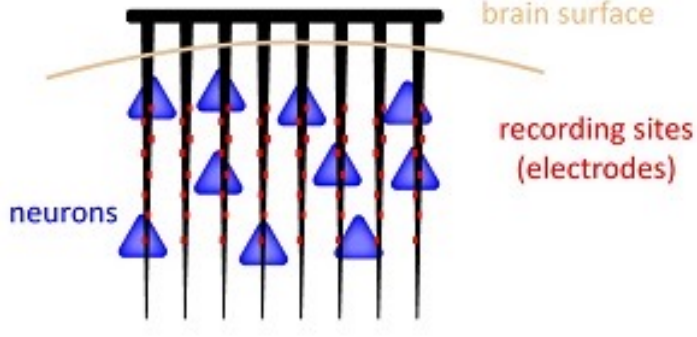




Patch-clamp recording (tracks 1 neuron at a time)

(*How to measure brain activity in animals,* 2018)

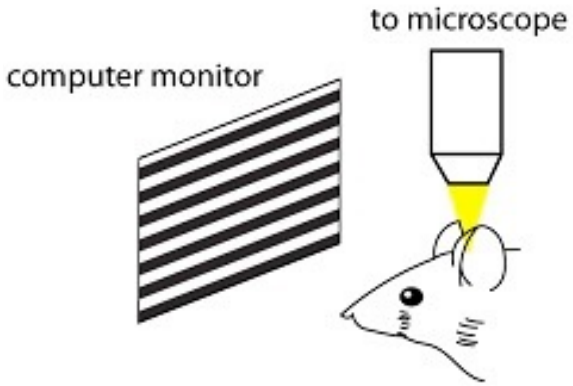
Prelude – neural correlates of cognition and complex behavior

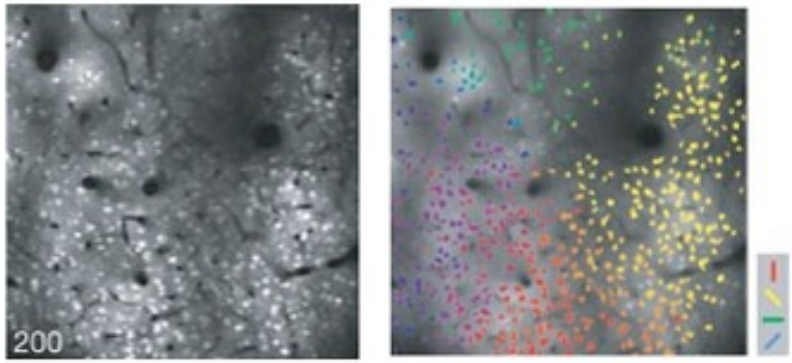


Multi-electrode recording (tracks ~10 – 1000 neurons)

(*How to measure brain activity in animals,* 2018)

Prelude – neural correlates of cognition and complex behavior



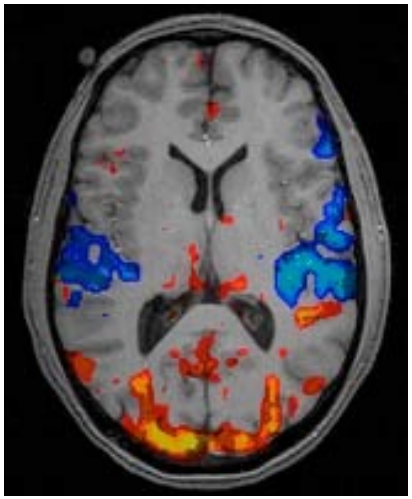


Fluorescence Imaging (tracks ~100 – 1000 neurons)

(*How to measure brain activity in animals,* 2018)

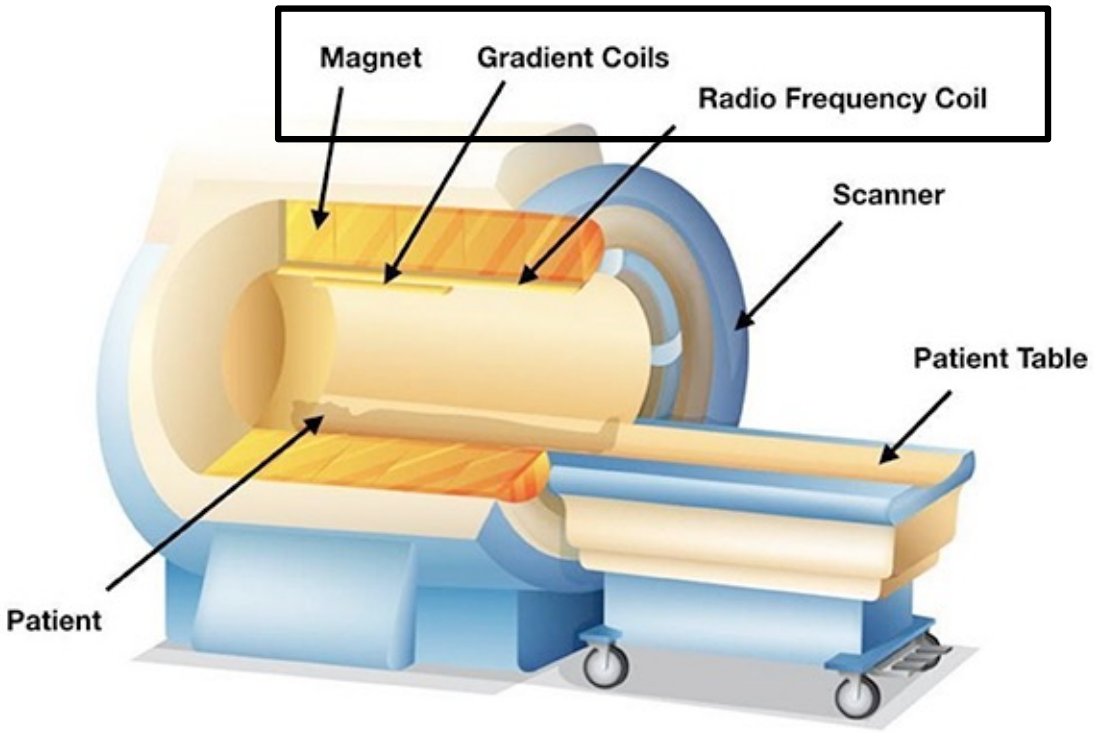
Prelude – neural correlates of cognition and complex behavior

Functional Magnetic Resonance Imaging
(records ~100,000 neurons in a single voxel)



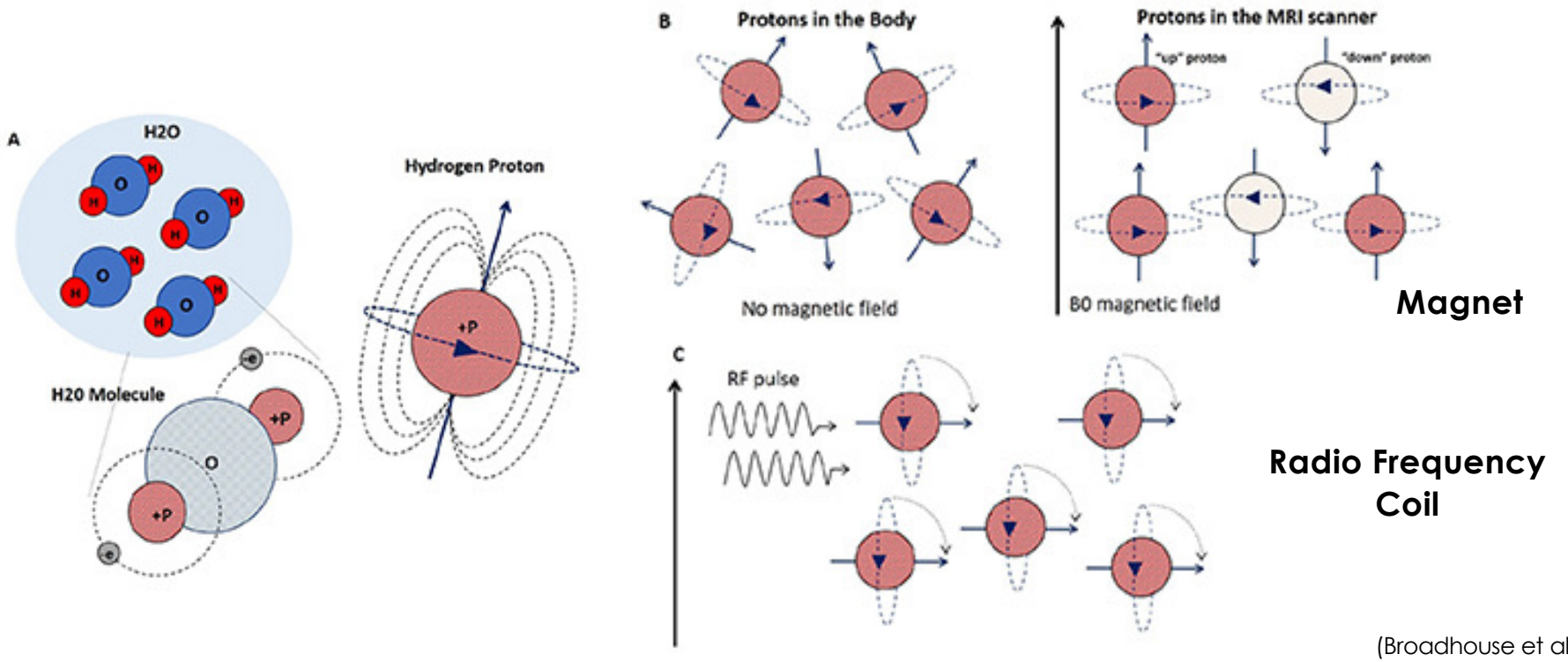
(*How FMRI works*, 2022)

fMRI Basics – what is functional neuroimaging?



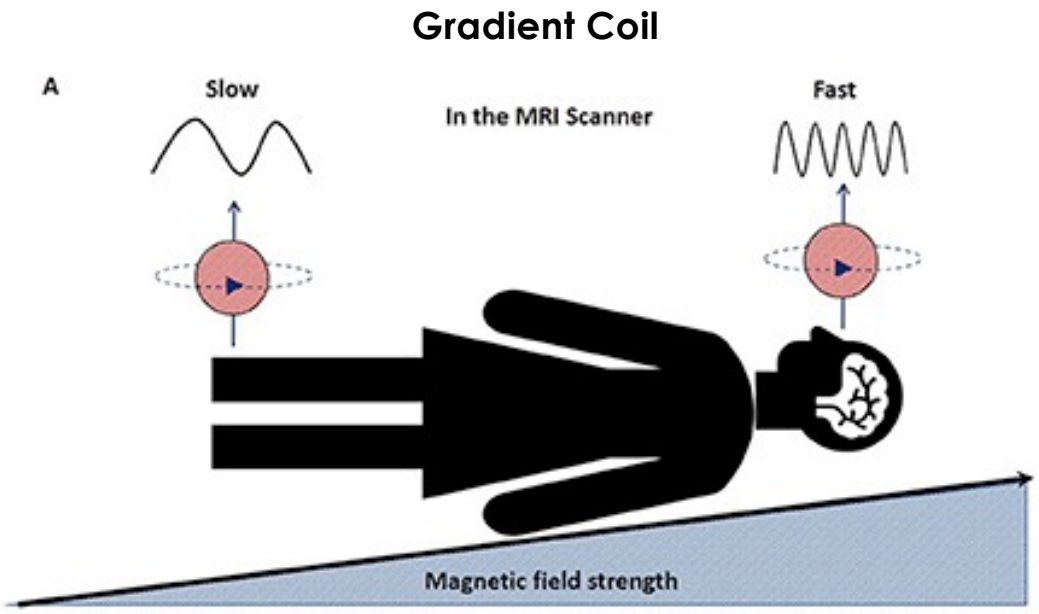
(Amanamba et al., 2020)

MRI Basics – the physics



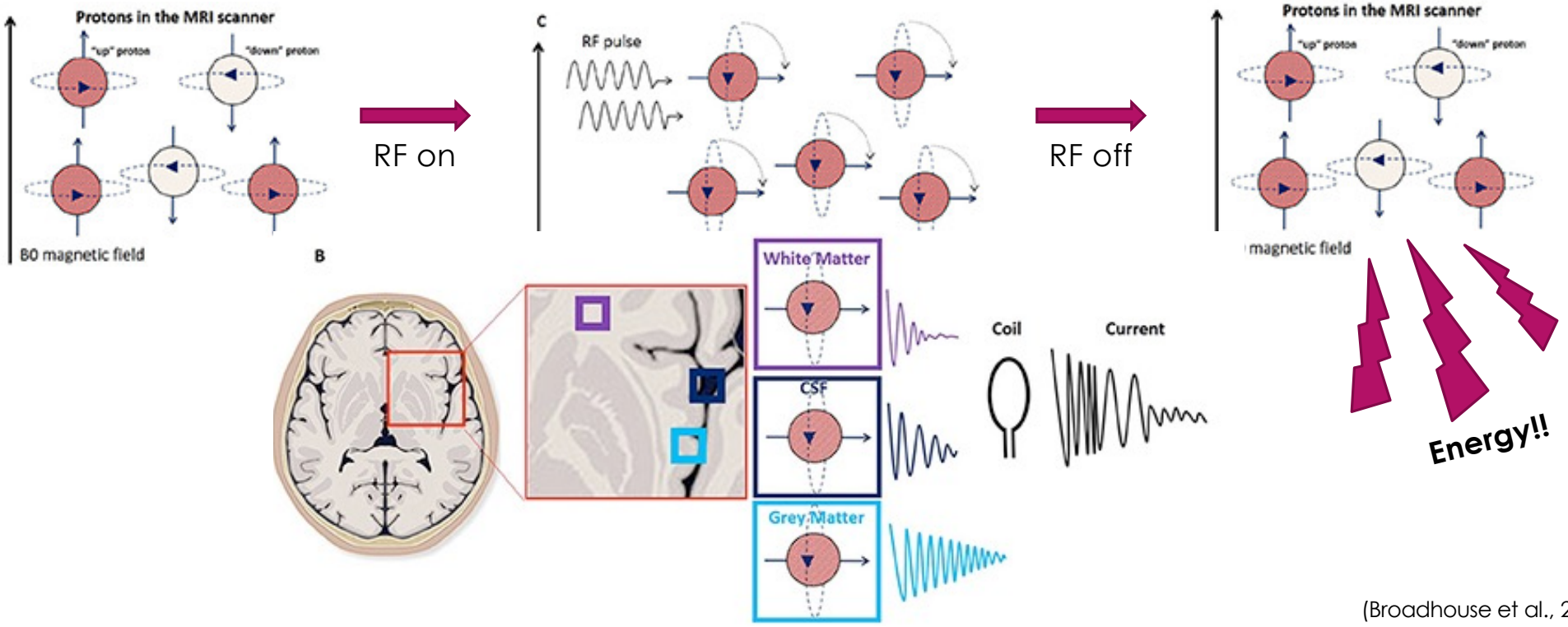
(Broadhouse et al., 2019)

MRI Basics – the physics



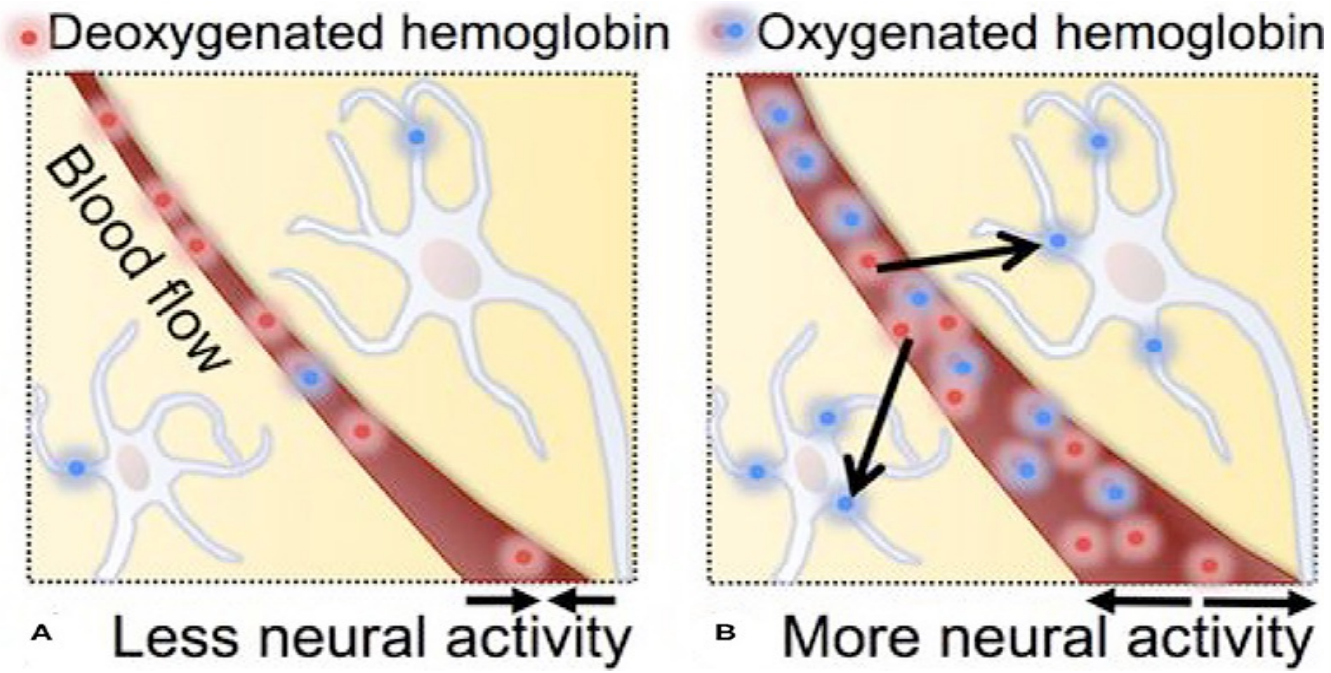
(Broadhouse et al., 2019)

MRI Basics – the physics



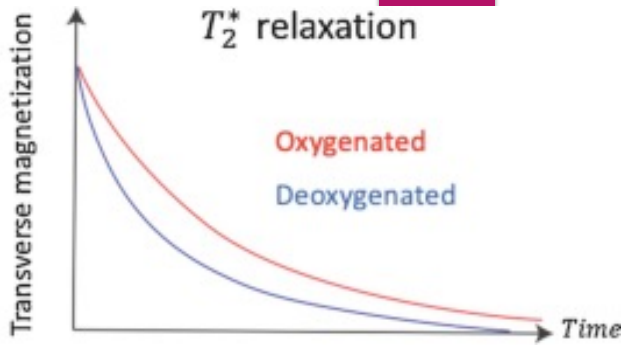
(Broadhouse et al., 2019)

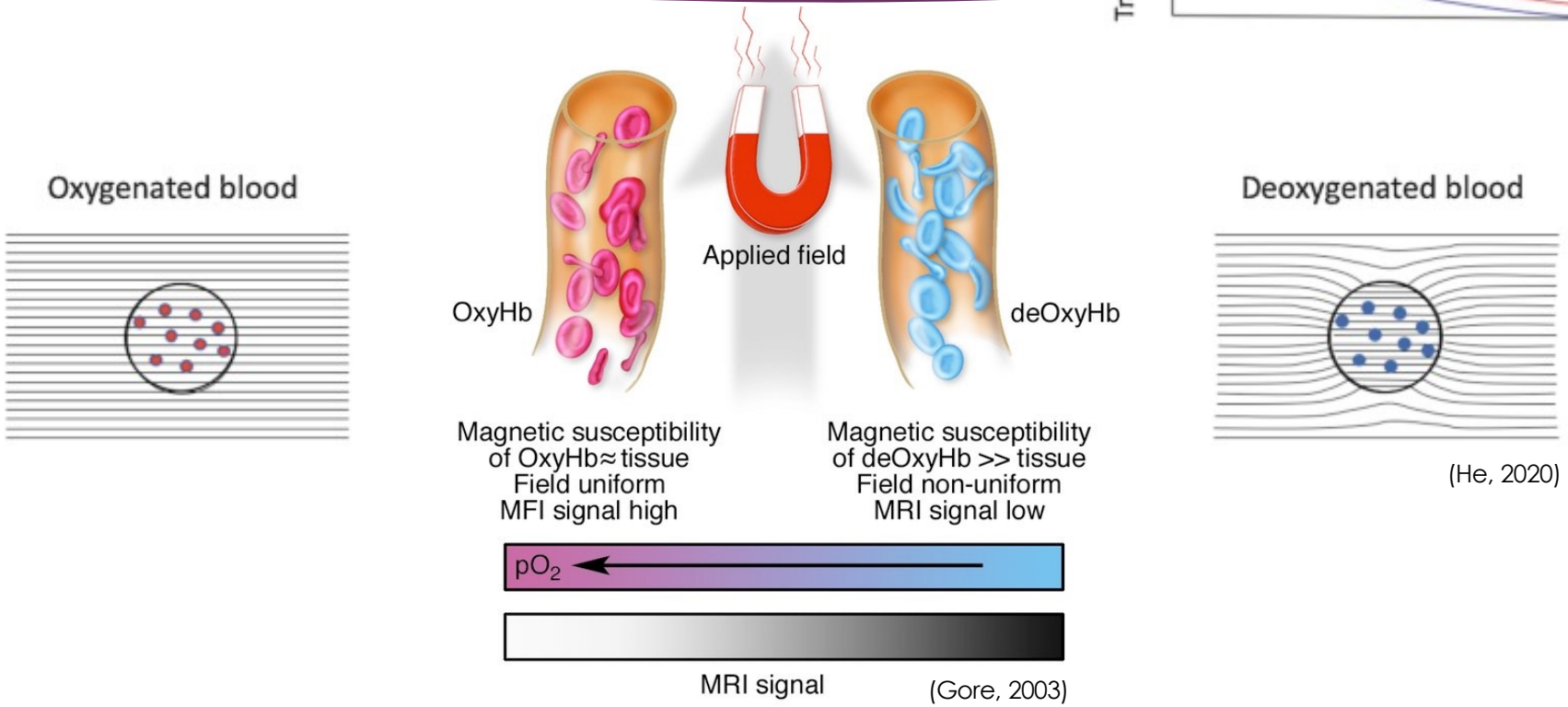
fMRI Basics – the physiology



(Amanamba et al., 2020)

fMRI Basics – the physiology

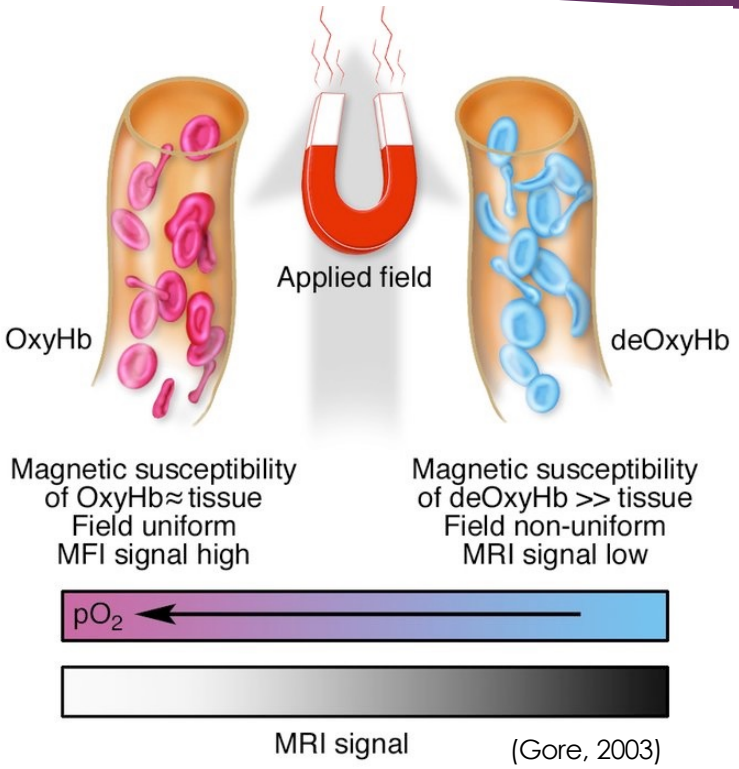




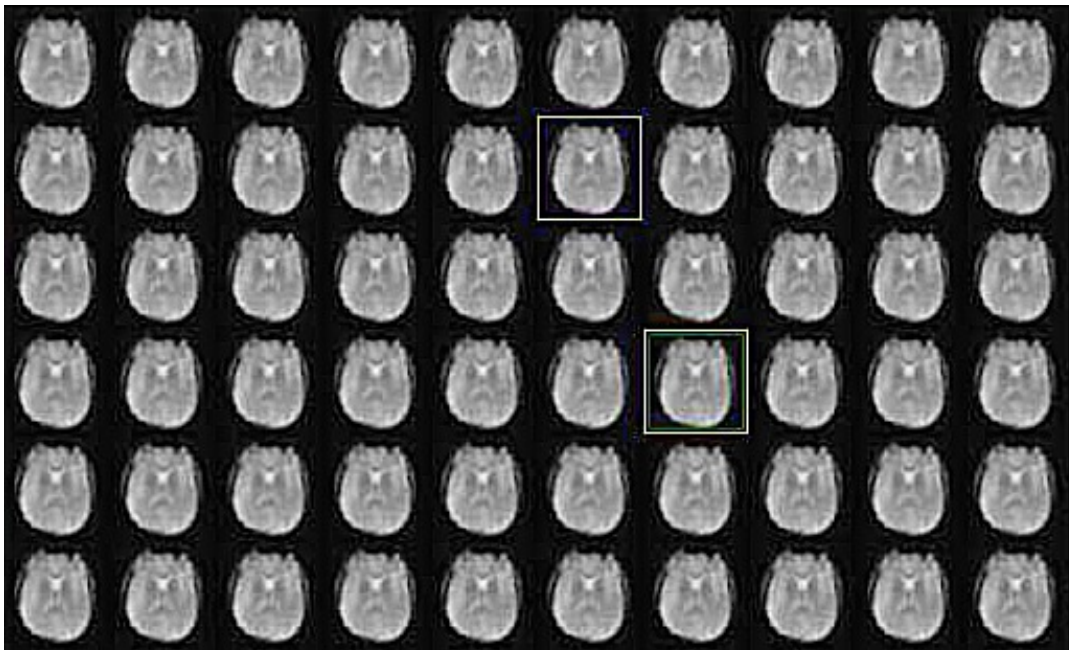
(He, 2020)

(Gore, 2003)

fMRI Basics – the physiology

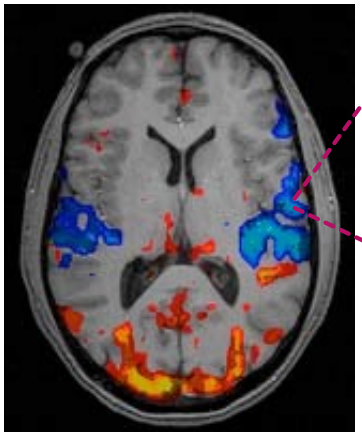


(Gore, 2003)

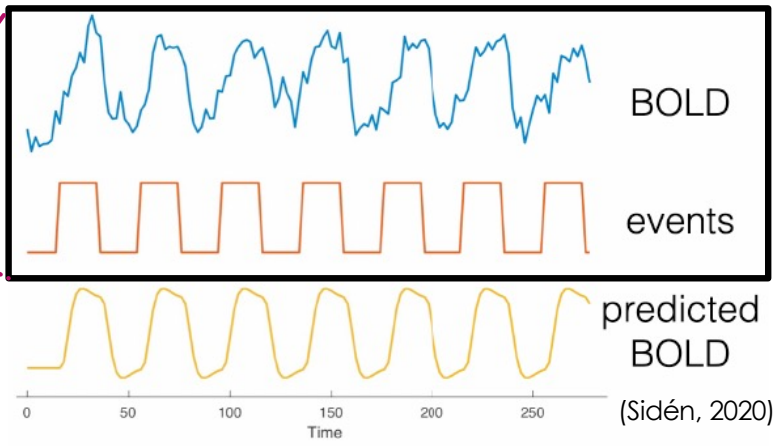


(*Magnetism*)

fMRI Basics – commonly used analyses

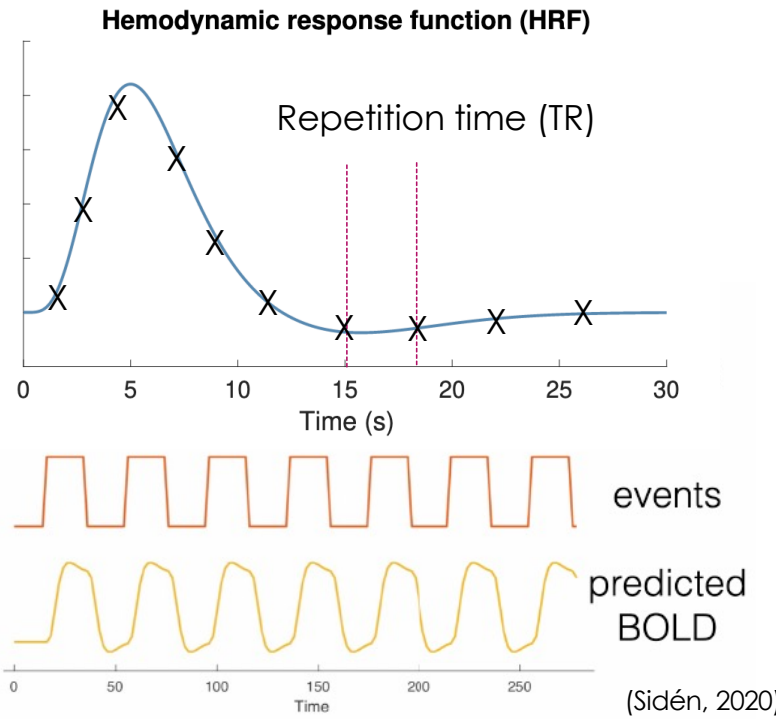


(*How FMRI works* 2022)



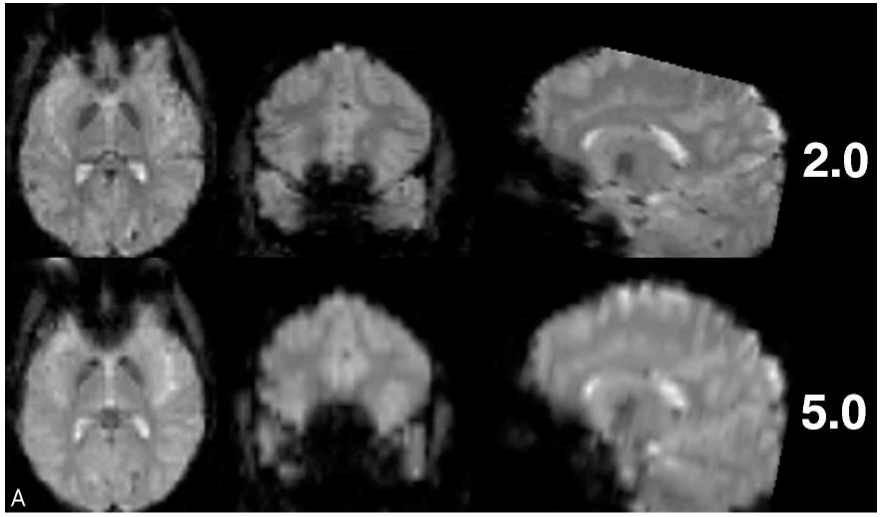
(Sidén, 2020)

fMRI Basics – pros and cons



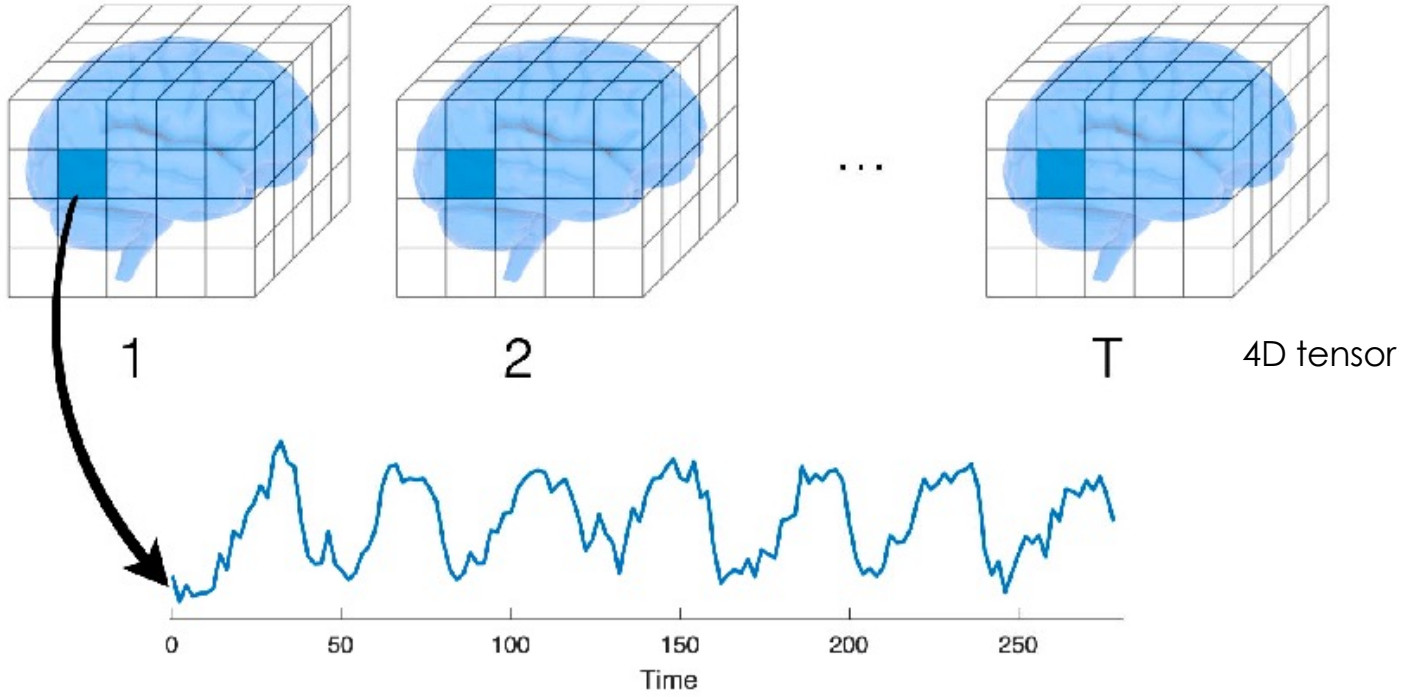
(Sidén, 2020)

Voxel size (in mm)



(Schmitz et al., 2005)

fMRI Data Formats



(Sidén, 2020)

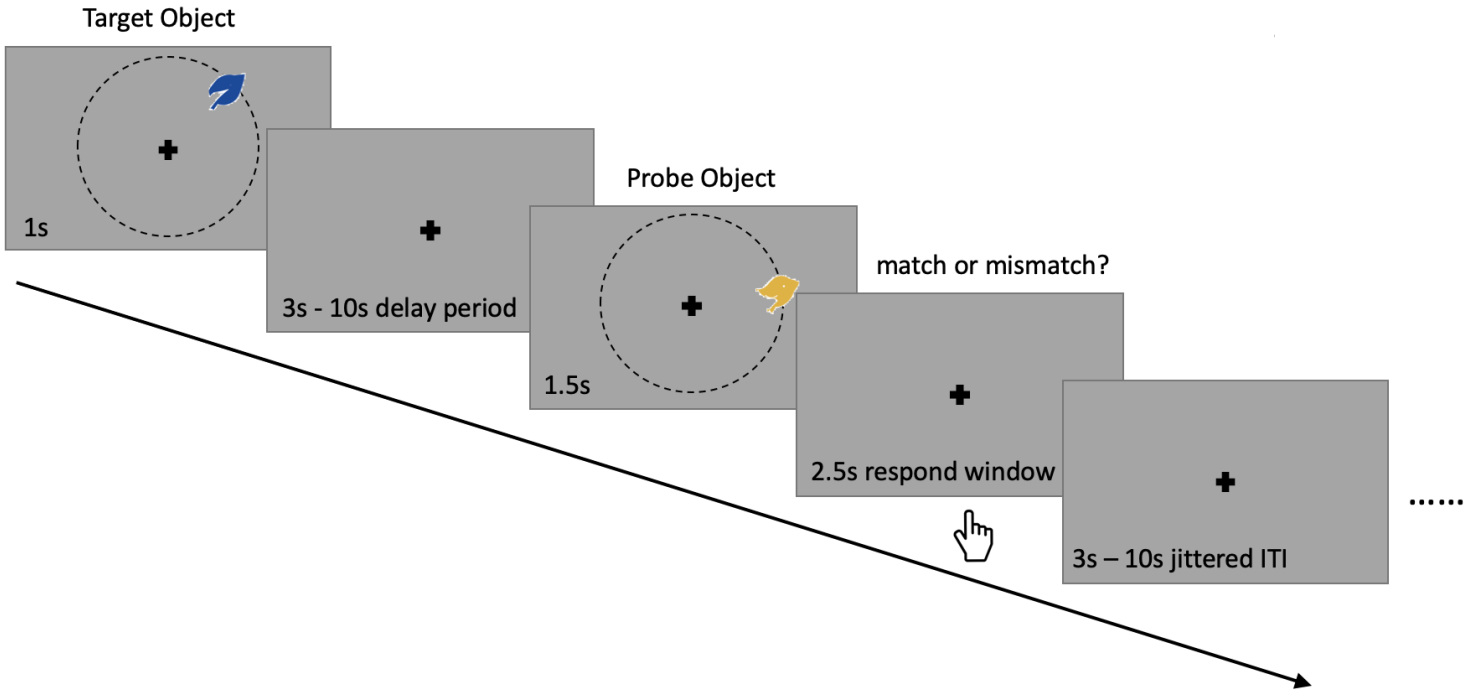
fMRI dataset - experiment overview

Participants: 7 healthy adults

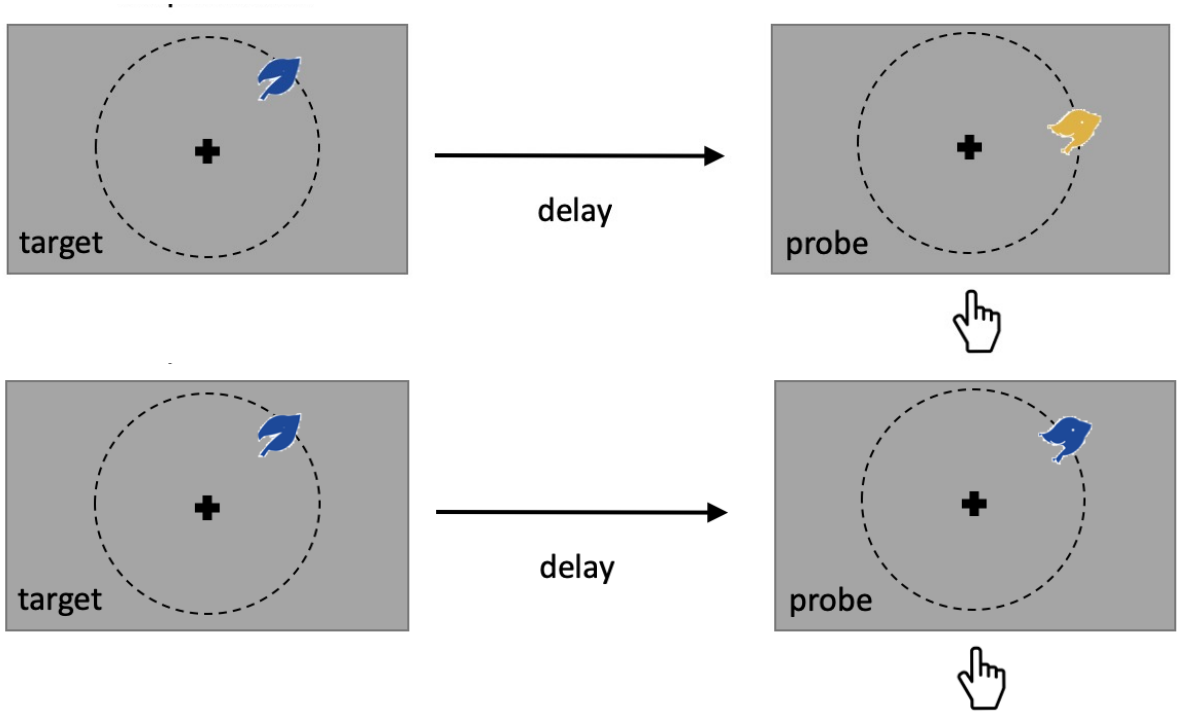
Computer-based Training: 2-hour-long, 288 trials of working memory task

Longitudinal fMRI Recording: 5 sessions of in-scanner working memory task, 240 trials each

fMRI dataset – experiment overview



fMRI dataset – experiment overview

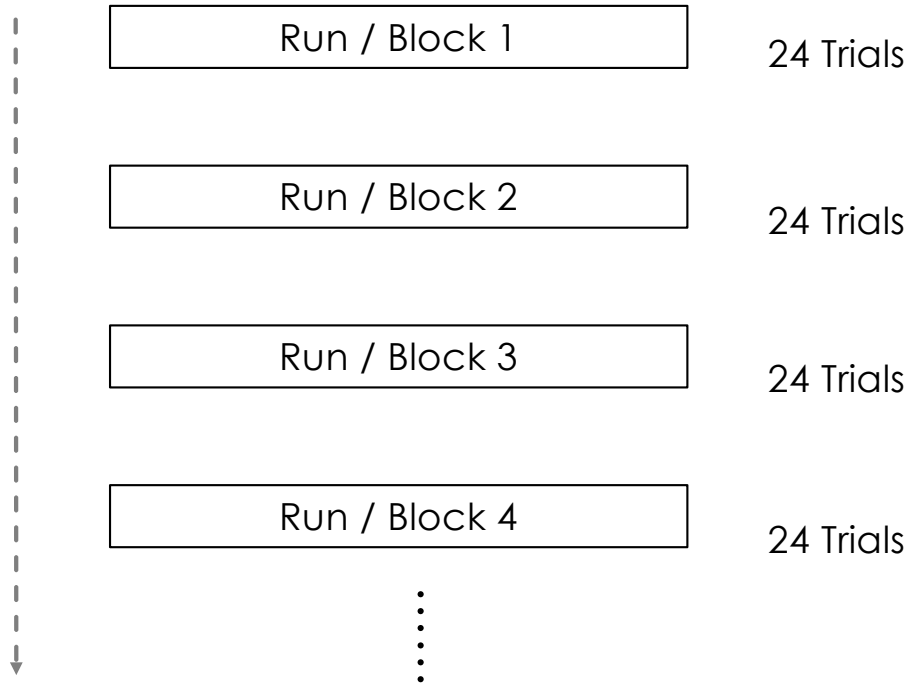


Correct Response

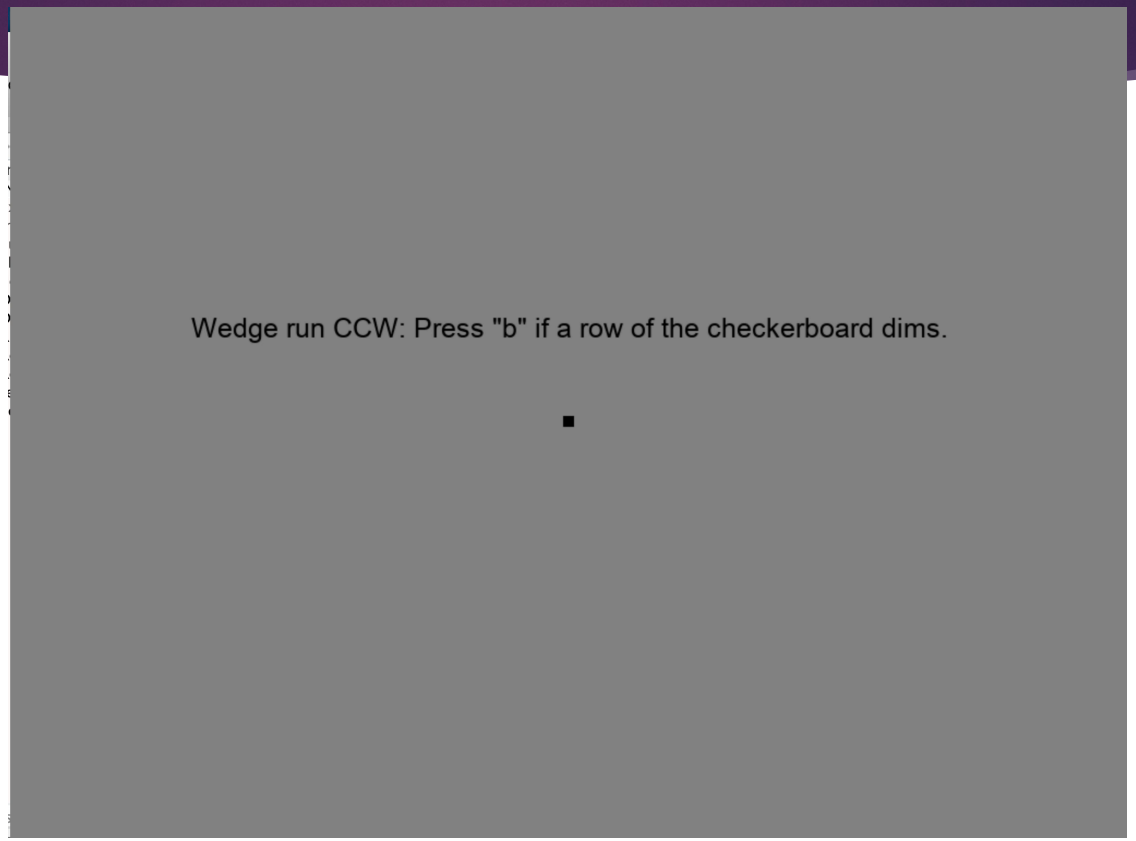
Non-match location

Match location

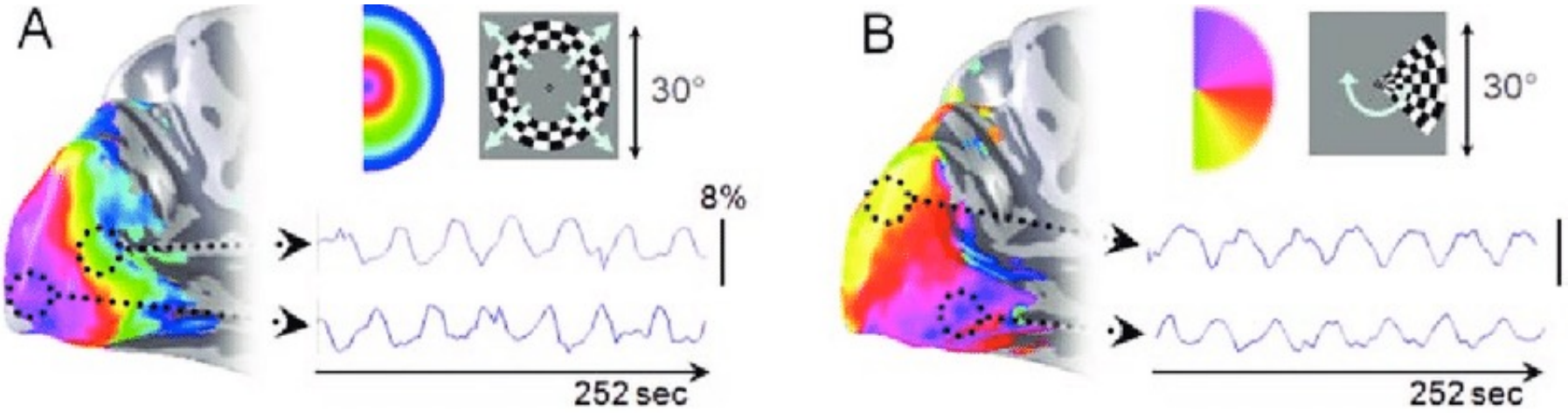
fMRI dataset – experiment overview



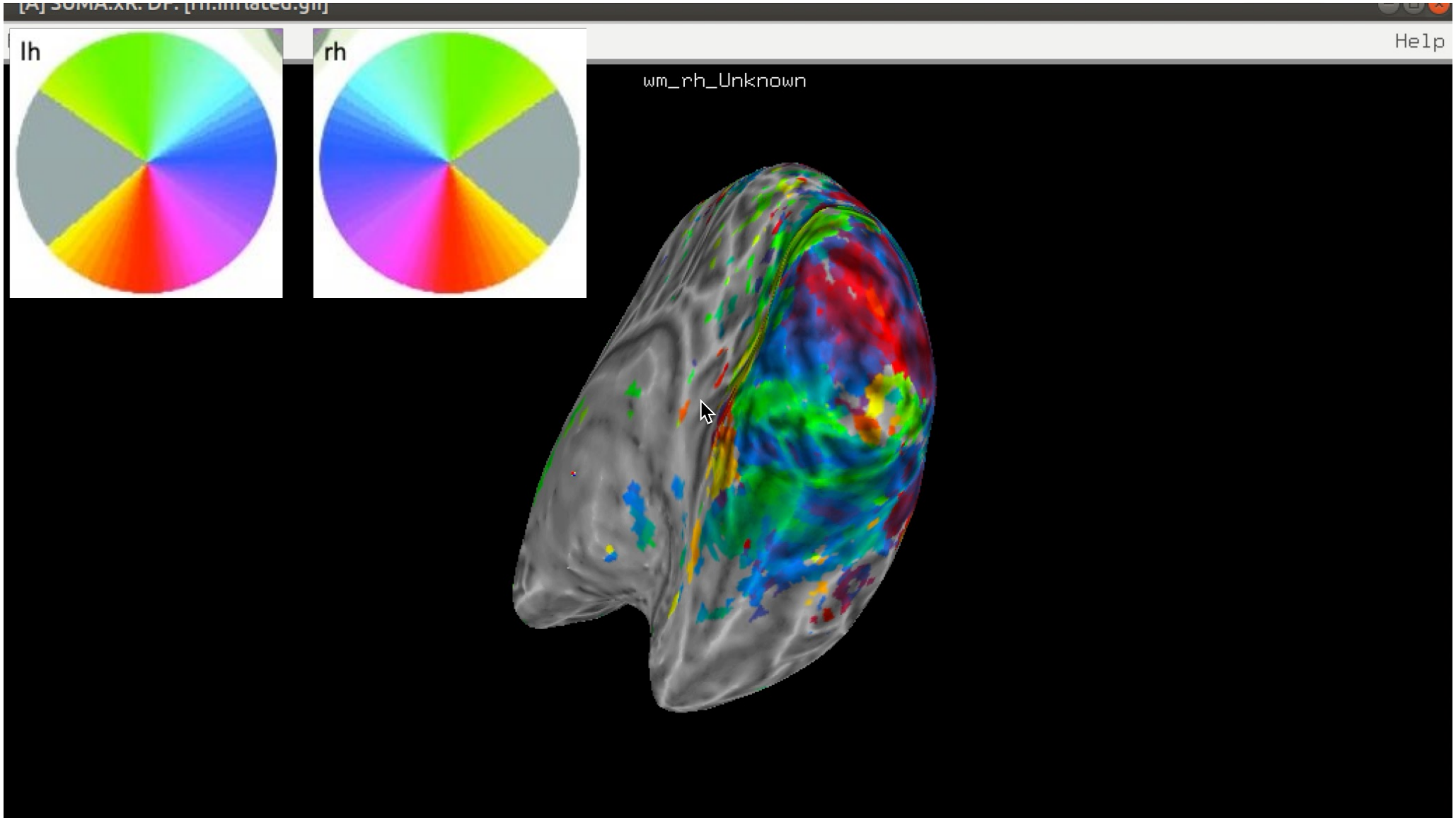
Retinotopic mapping



Retinotopic mapping



(Mckeefry et al., 2009)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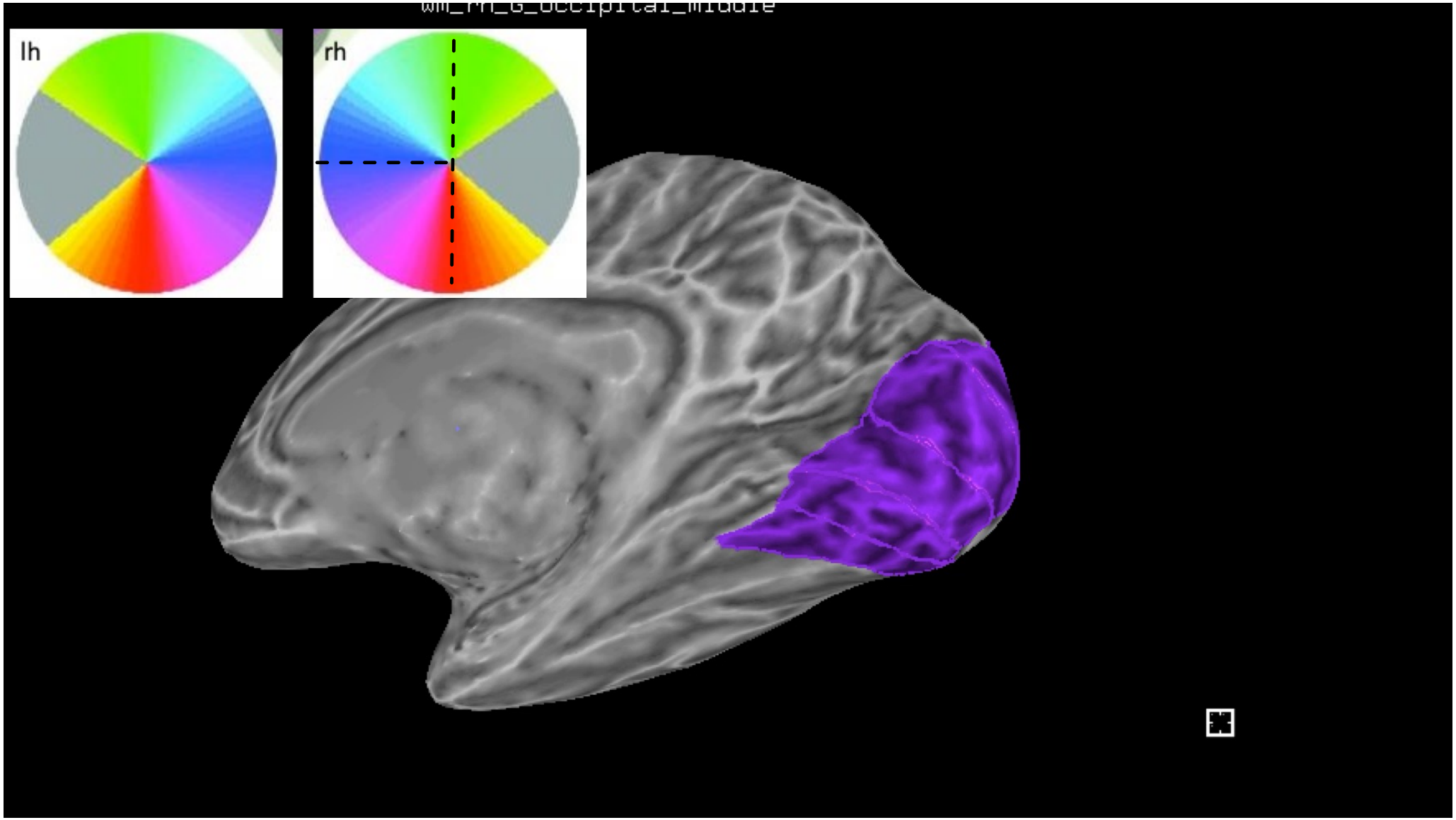
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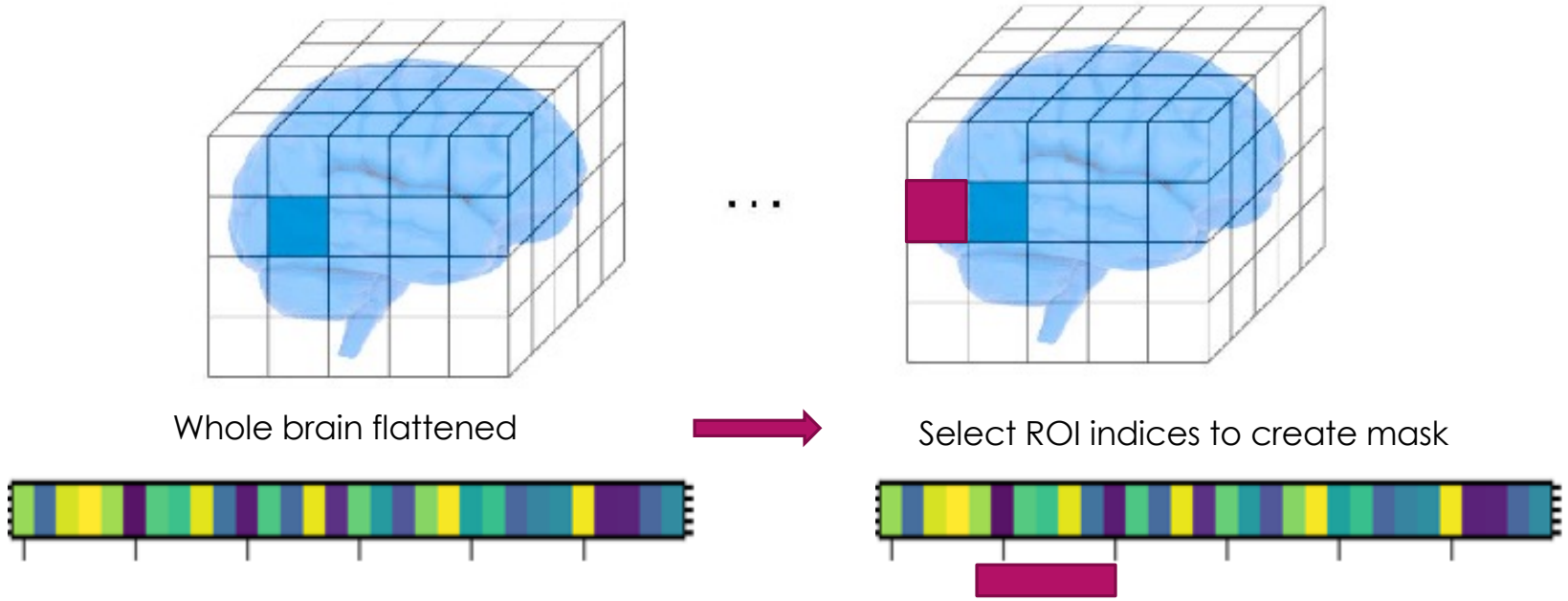
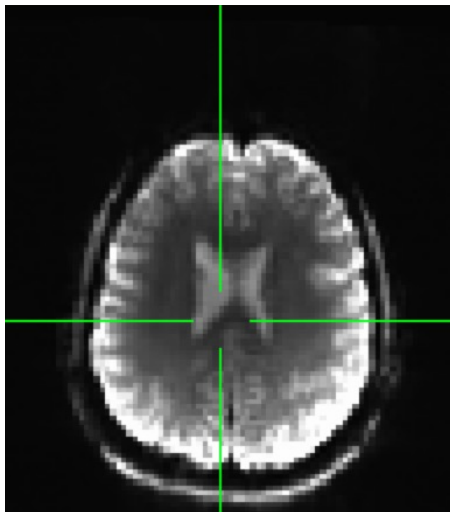
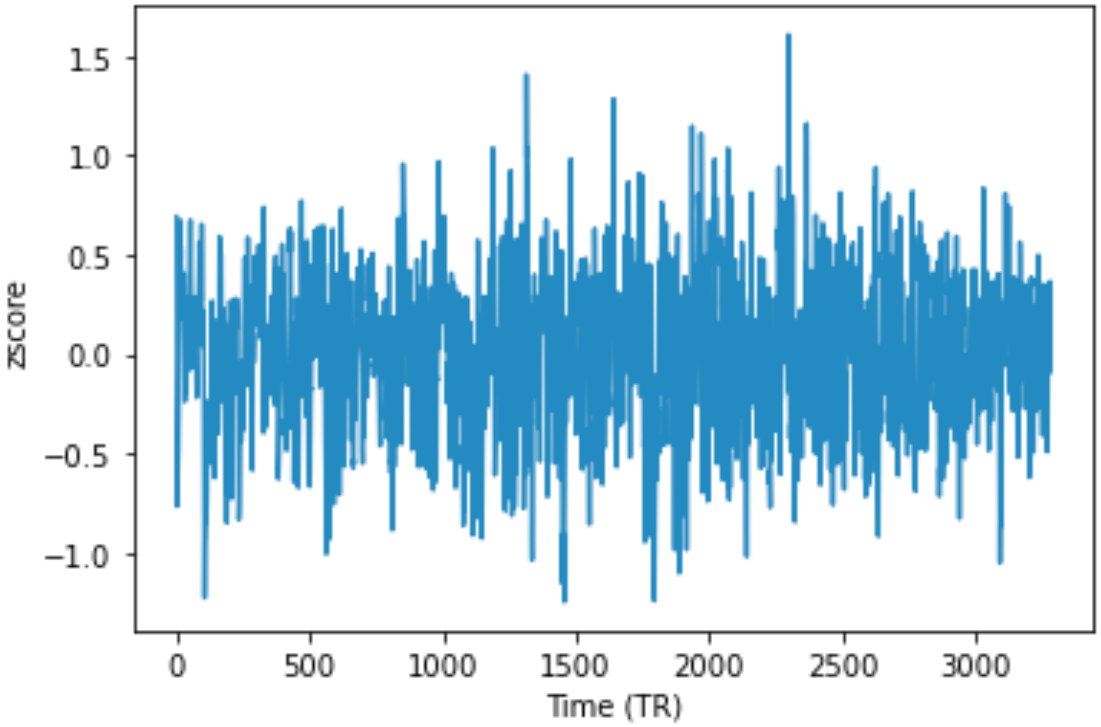
Region of interest (ROI) masks from retinotopy



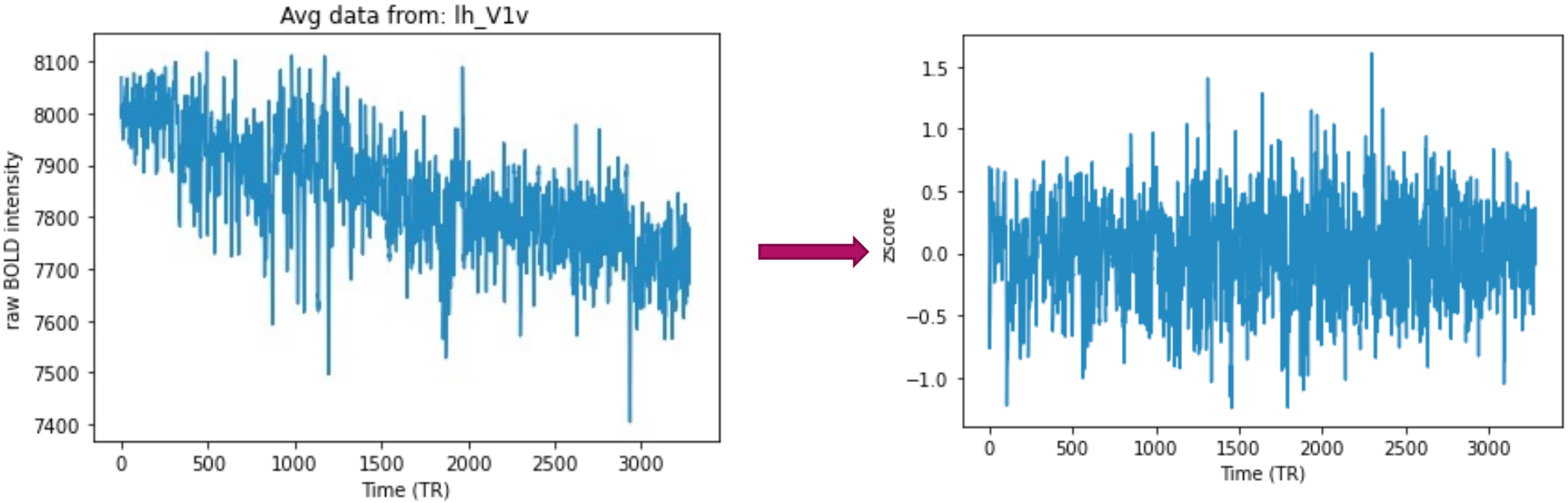
(Sidén, 2020)

Task 1 – Visualize fMRI data in python



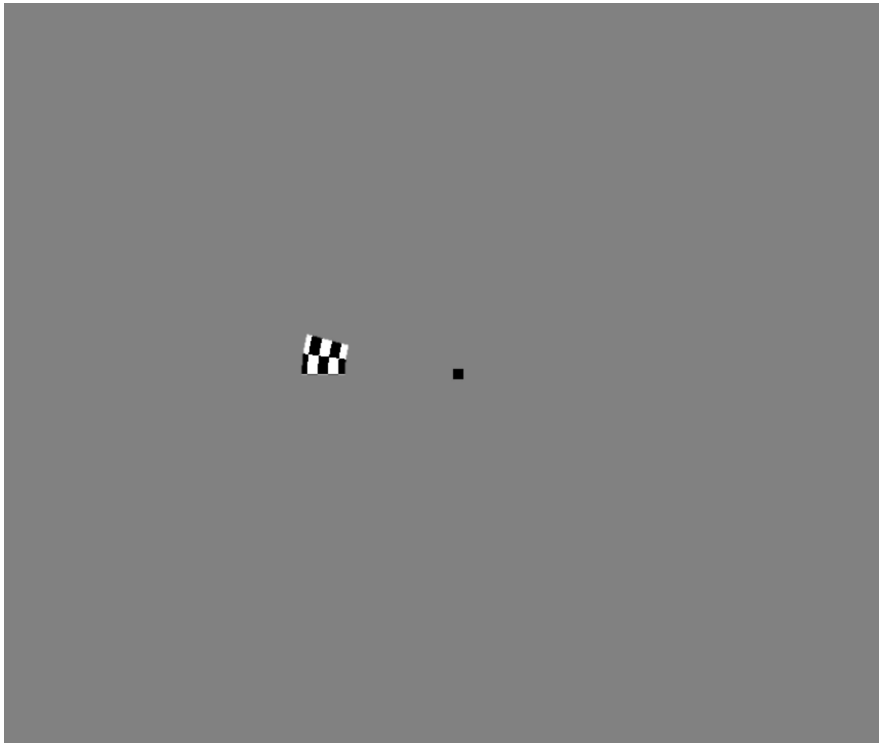


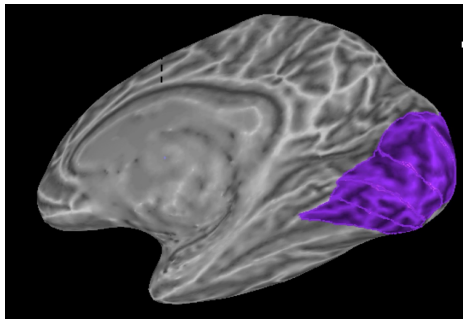
Importance of z-scoring fMRI data



Task 2 – Extract spatially selective voxels via ANOVA

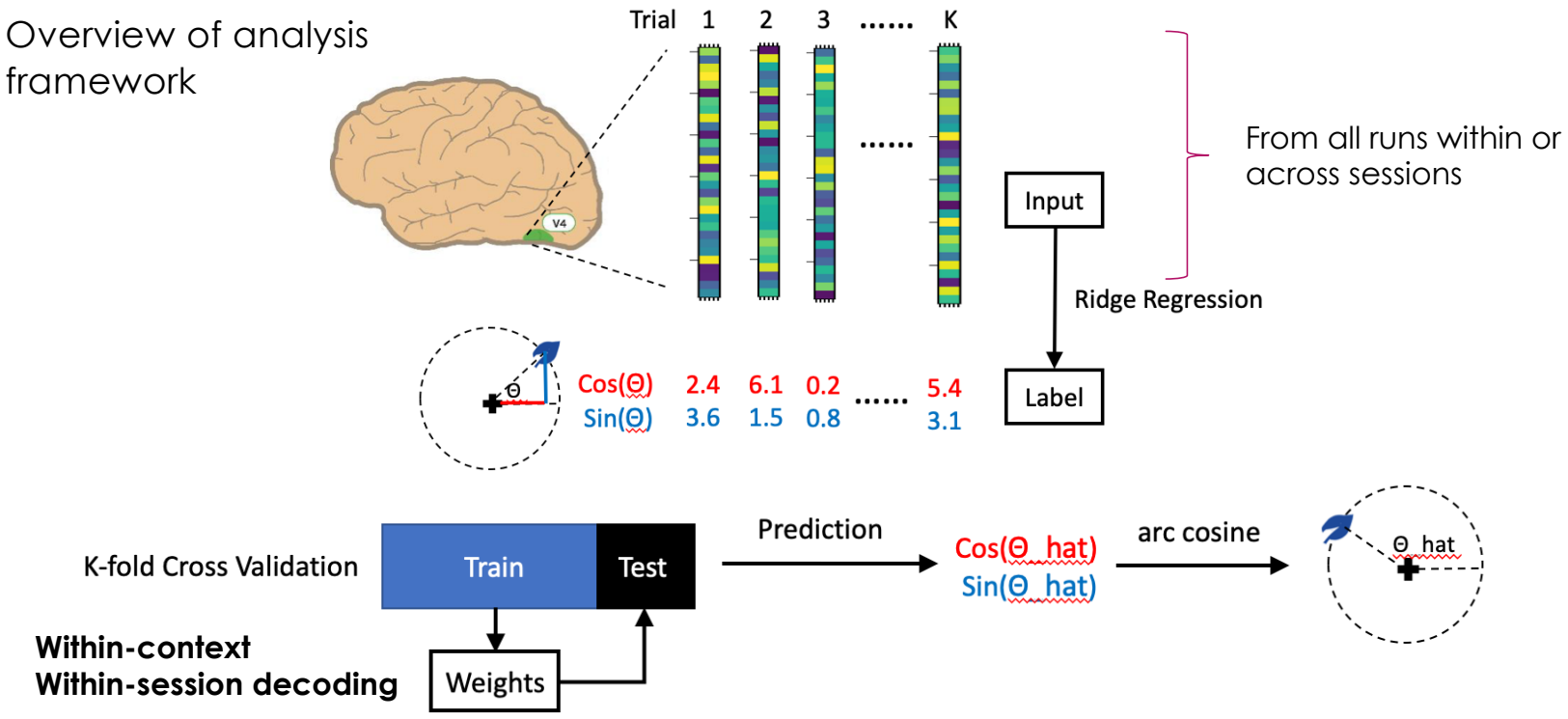
Our localizer task



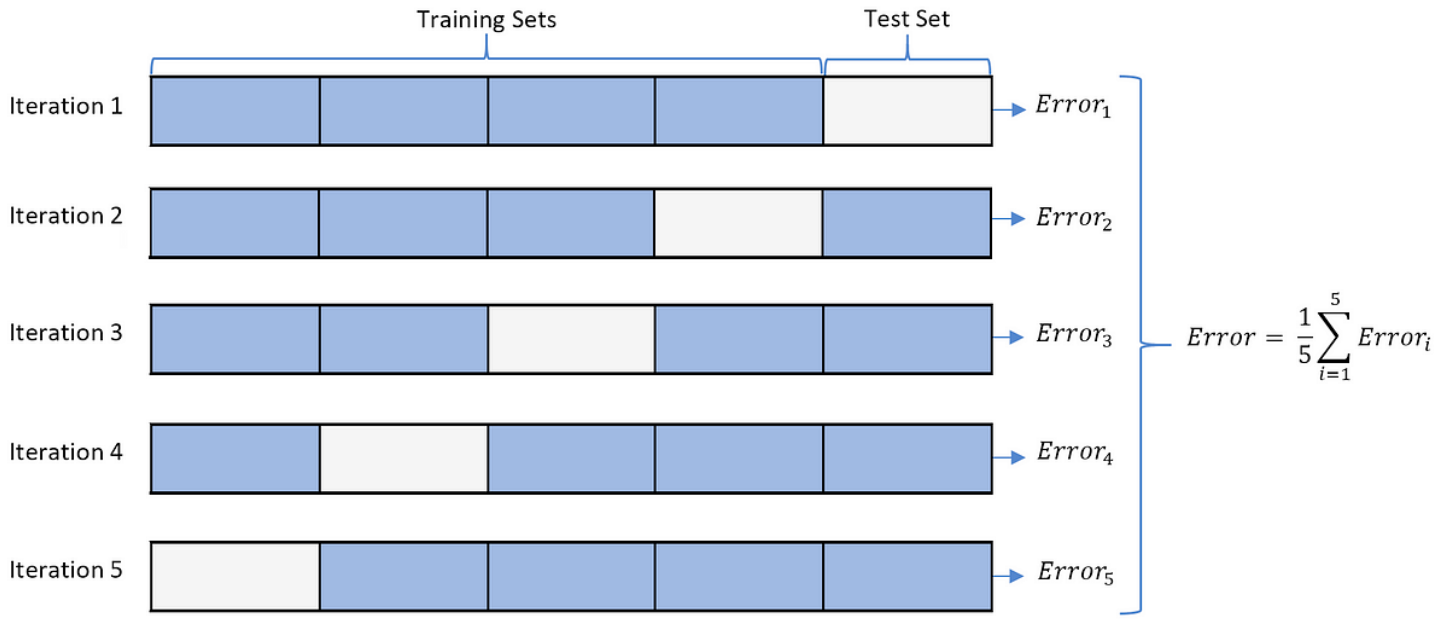


Task 3 – Decode feature location via regularized linear regression

Overview of analysis framework



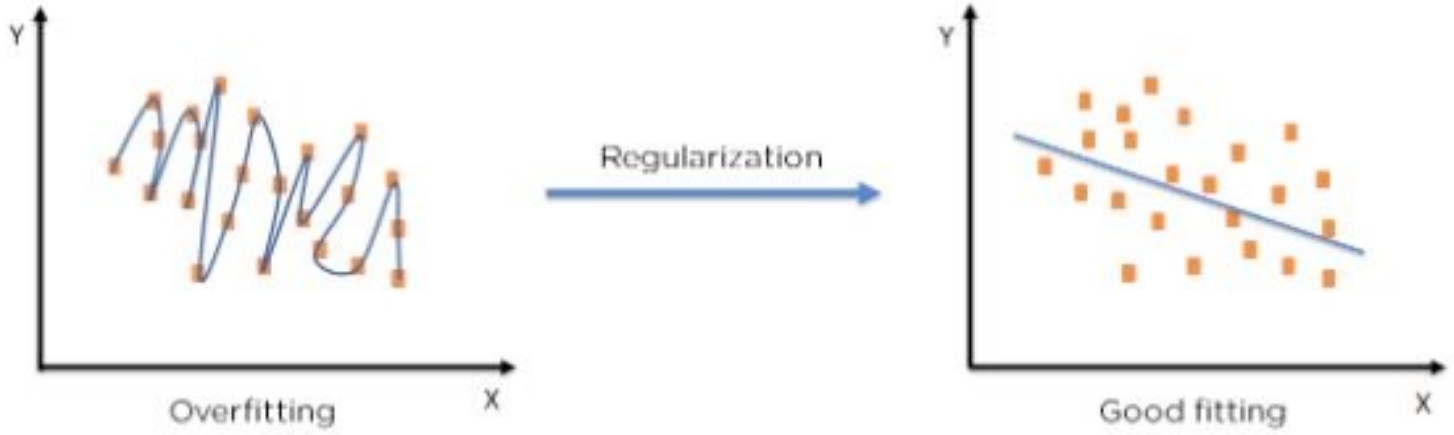
Importance of cross-validation



(https://towardsdatascience.com/cross-validation-k-fold-vs-monte-carlo-e54df2fc179b)

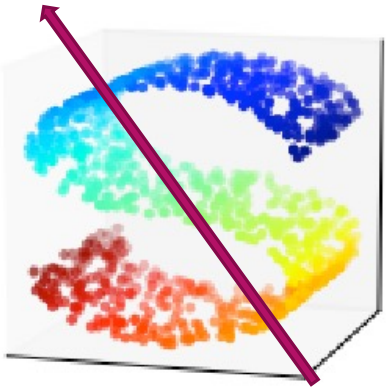
Importance of regularization

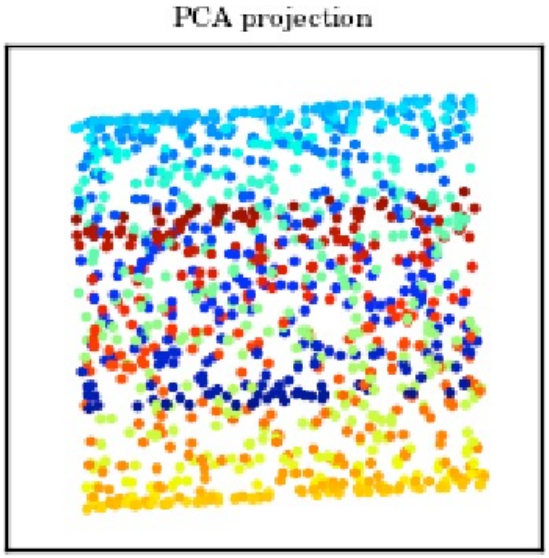
Especially important when K >> N



(https://www.simplilearn.com/tutorials/machine-learning-tutorial/regularization-in-machine-learning)

Task 4 – Visualize neural representations of feature location via MDS

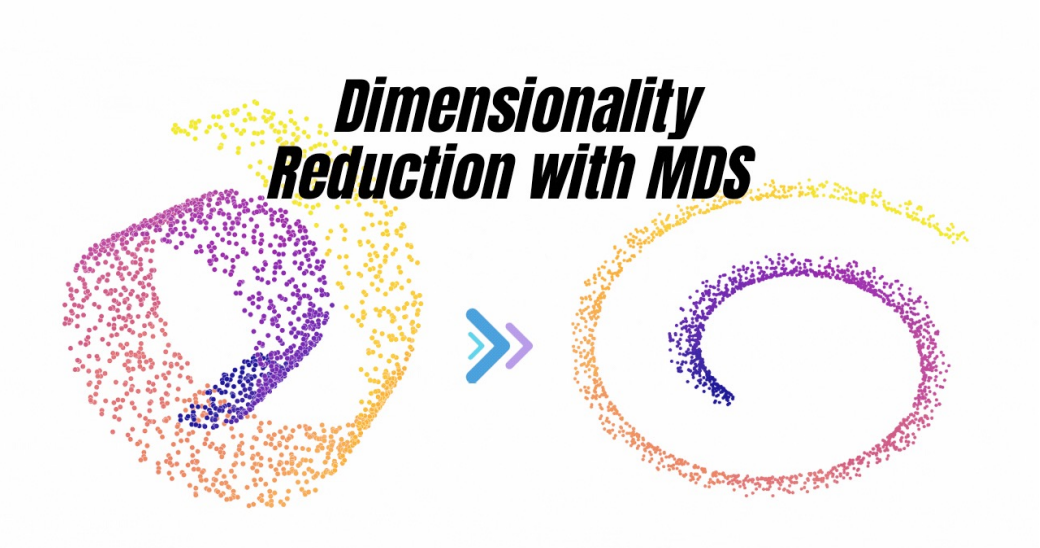




PCA aims to find axes that captures maximum variance among datapoints

(Ornek & Vural, 2017)

Task 4 – Visualize neural representations of feature location via MDS



MDS aims to find axes that preserve the local distance between datapoints

(Dobilas, 2021)

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Citations

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