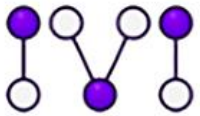

INTERDISCIPLINARY VISUAL INTELLIGENCE LAB

Colloquium Sep 5th, 2018

Functional Magnetic Resonance (FMRI) Imaging

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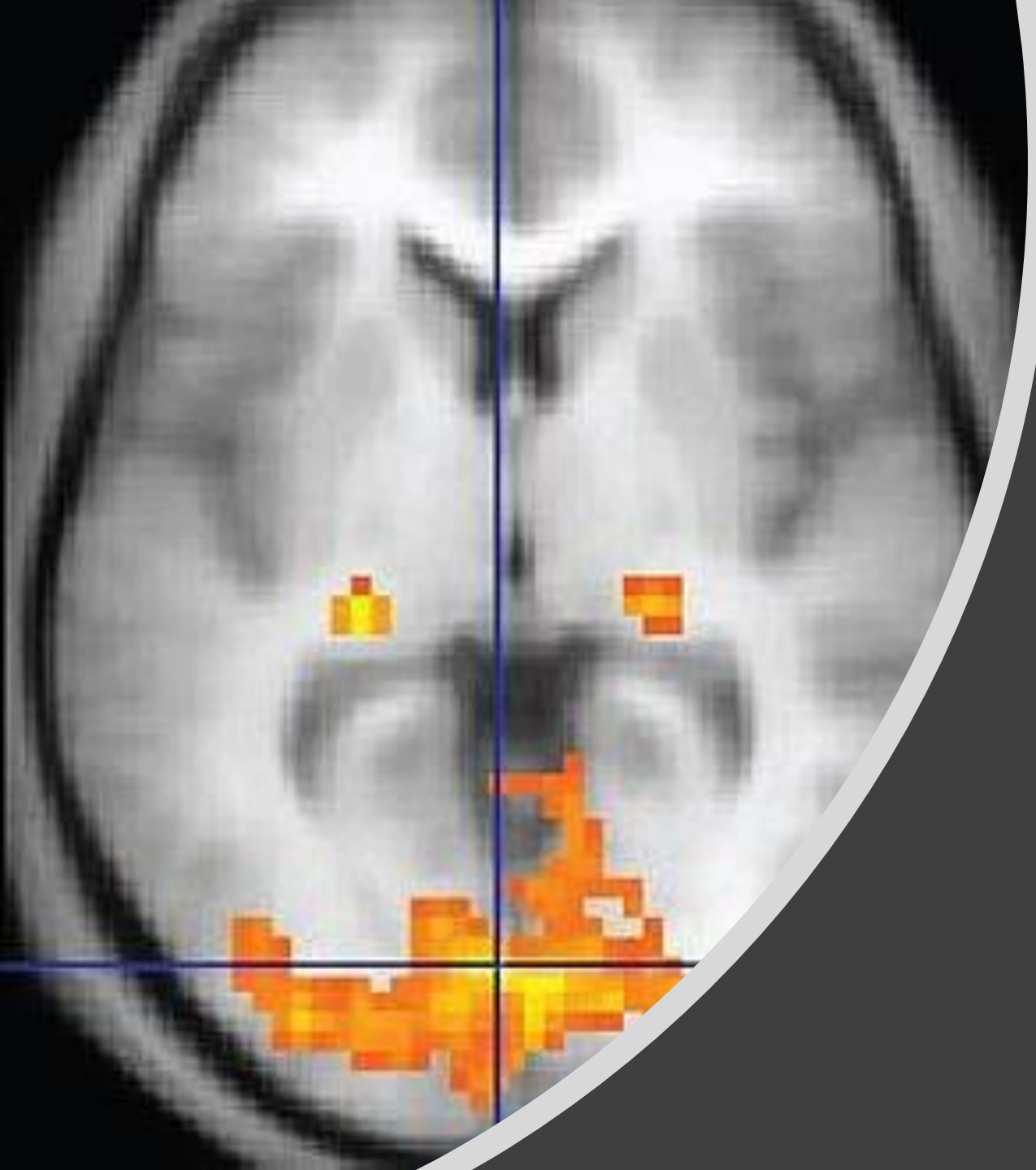
Can we predict choices?



Functional Magnetic Resonance Imaging (FMRI)

- FMRI measures brain activity by detecting changes associated with blood flow.
- Blood-oxygen-level dependent imaging (BOLD Contrast)
- Hemodynamic Response (HDR)

Why study FMRI data?

- Mapping brain functionality!

Our research aim is to understand:

- Risk Preferences
- Role of Memory

Risk Preferences

How can we predict, when consumers make choices in everyday life, whether they will be risk-seeking or risk-averse?

Experiences Vs Gambles

In our present work, we are curious to know whether consumers access extreme reference points in memory in order to make choices on experiences (vs. money)

Experiment Setup

- Participants were 46 adult volunteers.
- They were engaged in a behavioral decision-making task in which they had to repeatedly choose between two music songs (i.e., two experiences) or two monetary gambles
- Before entering the scanner, participants were engaged in a practice version of the behavioral task to familiarize them with the task structure
- Participants indicated their most preferred music genre from a list of 22 genres
- To put the participants into a state of monetary gains, they were provided with a $25 cash endowment

songs trial #1

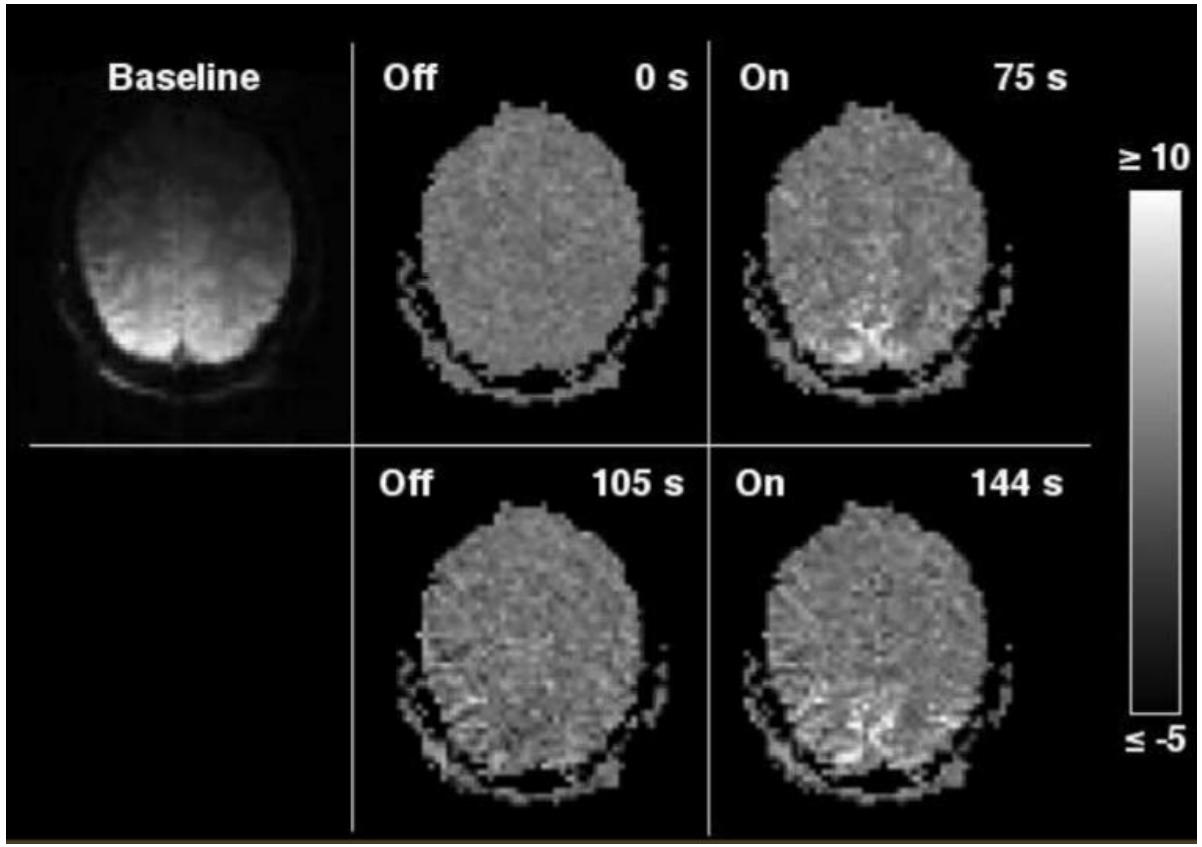
compare

<< choose now >>


A
B
16
14
12
10
8
6
4
2
0
people
-5 -4 -3 -2 -1 0 1 2 3 4 5
rating
16
14
12
10
8
6
4
2
0
-5 -4 -3 -2 -1 0 1 2 3 4 5
rating

Raw FMRI Data

- Siemens Skyra 3 Tesla fMRI scanner
- 441 volumes with 33 slices in the transverse plane was obtained using single shot gradient-echo planar imaging
- TR = 1,000ms, TE = 30ms, flip angle = 90°
- Resolution = 2.5mm × 2.5mm × 2.5mm, and FOV = 240mm)



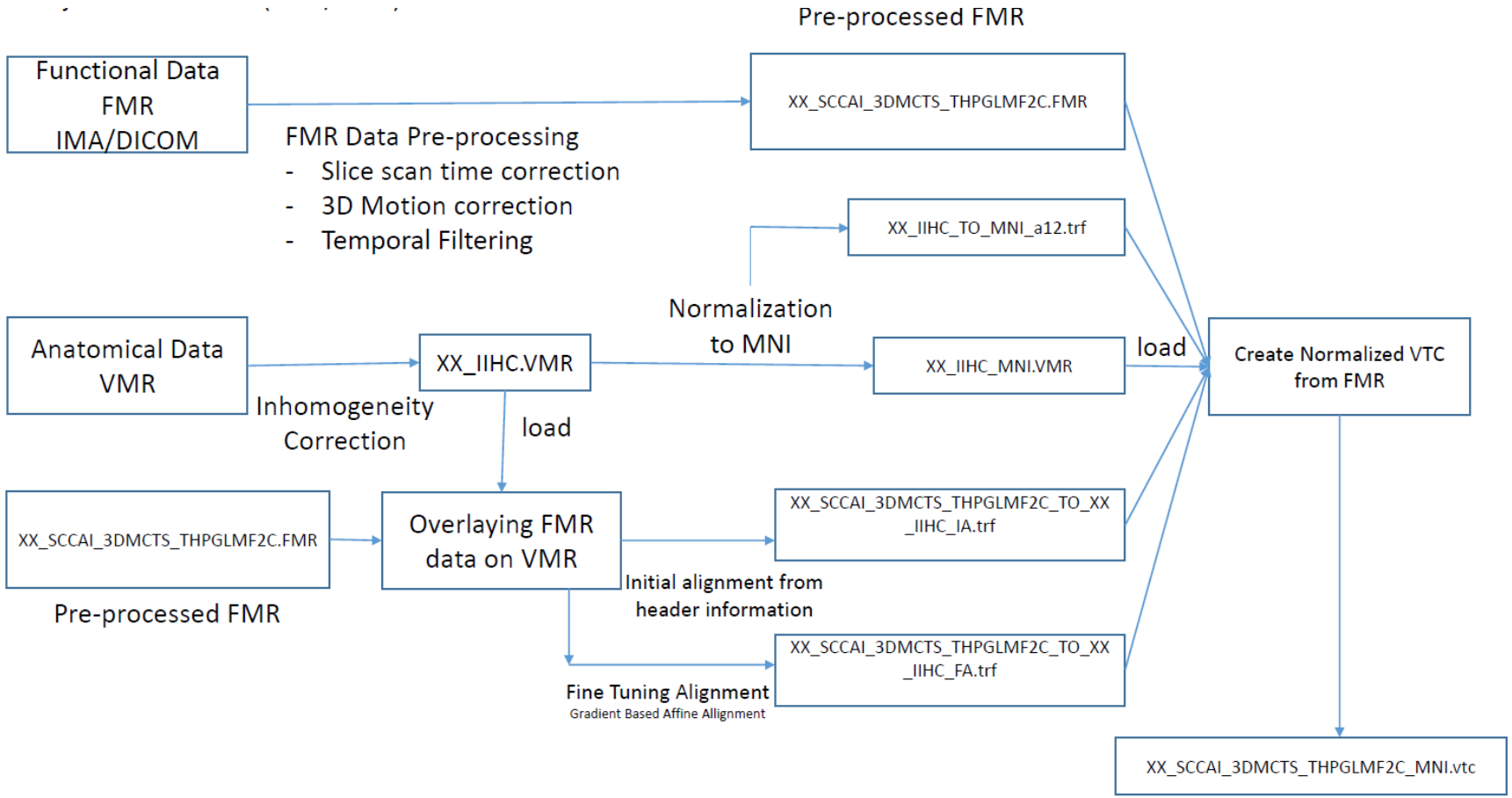
Visual Stimulation in Occipital cortex

https://www.ctsi.ucla.edu/education/files/publicview/training/docs/functional-mri-bookheimer.pdf

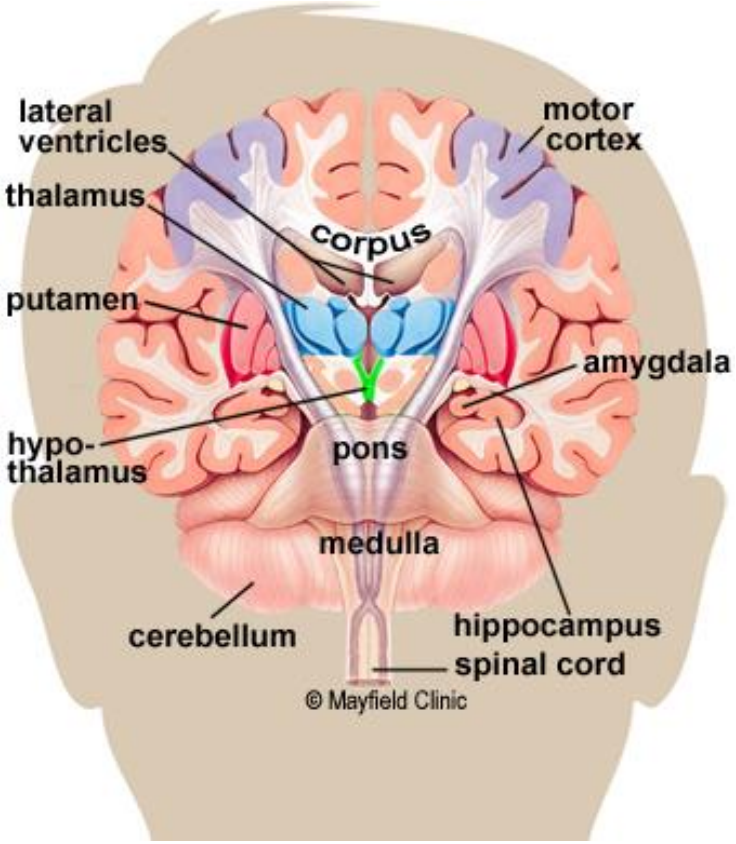
Behavioral Data

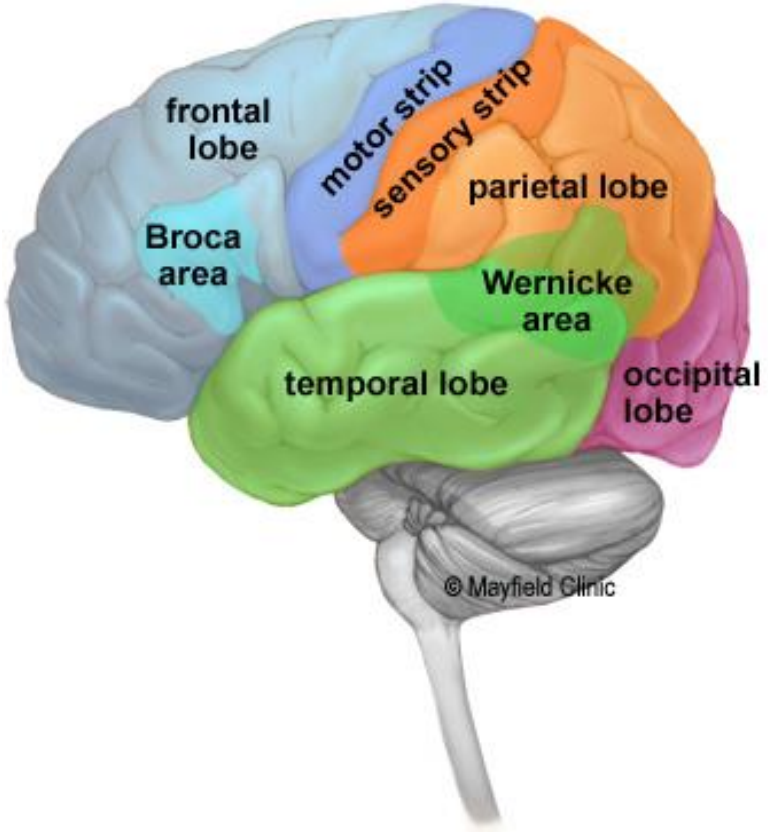
	High Variance	Low Variance
Experiences	57%	43%
Gambles	50.7%	49.3%

	s1	s2	s3	s4	s5	g1	g2	g3	g4	g5
Risky	13	22	23	23	26	19	23	29	23	26
Safe	13	20	22	23	18	24	20	16	22	18
No Choice	22	6	3	2	4	5	5	3	3	4



Data Pre Processing





Brain Anatomy

https://mayfieldclinic.com/pe-anatbrain.htm

Why we are considering these brain regions?

Hippocampus

- Located in the brain's temporal lobe, is where episodic memories are formed and indexed for later access.
- The LEFT hippocampus is more involved in the learning & memory of “facts”, “episodes”, “words”
- The hippocampus compares the present experience with past experience; processing through the hippocampus is necessary for learning and for memory consolidation to occur.

Amygdala

- Attaches emotional significance to memories. This is particularly important because strong emotional memories (e.g. those associated with shame, joy, love or grief) are difficult to forget.

https://www.vanderbilt.edu/olli/class-materials/Neuroscience_April4th.pdf

Regions of Interest

Defining Hippocampus region using BrainVoyager QX software

NameOfVOI: Hippocampus
ColorOfVOI: 122 82 24

NrOfVoxels: 7588
-2 -33 76
-2 -34 76
-2 -36 76
-2 -33 75
-2 -34 75
-2 -35 75
-2 -36 75
-2 -31 74
-2 -33 74
-2 -35 74
-2 -36 74
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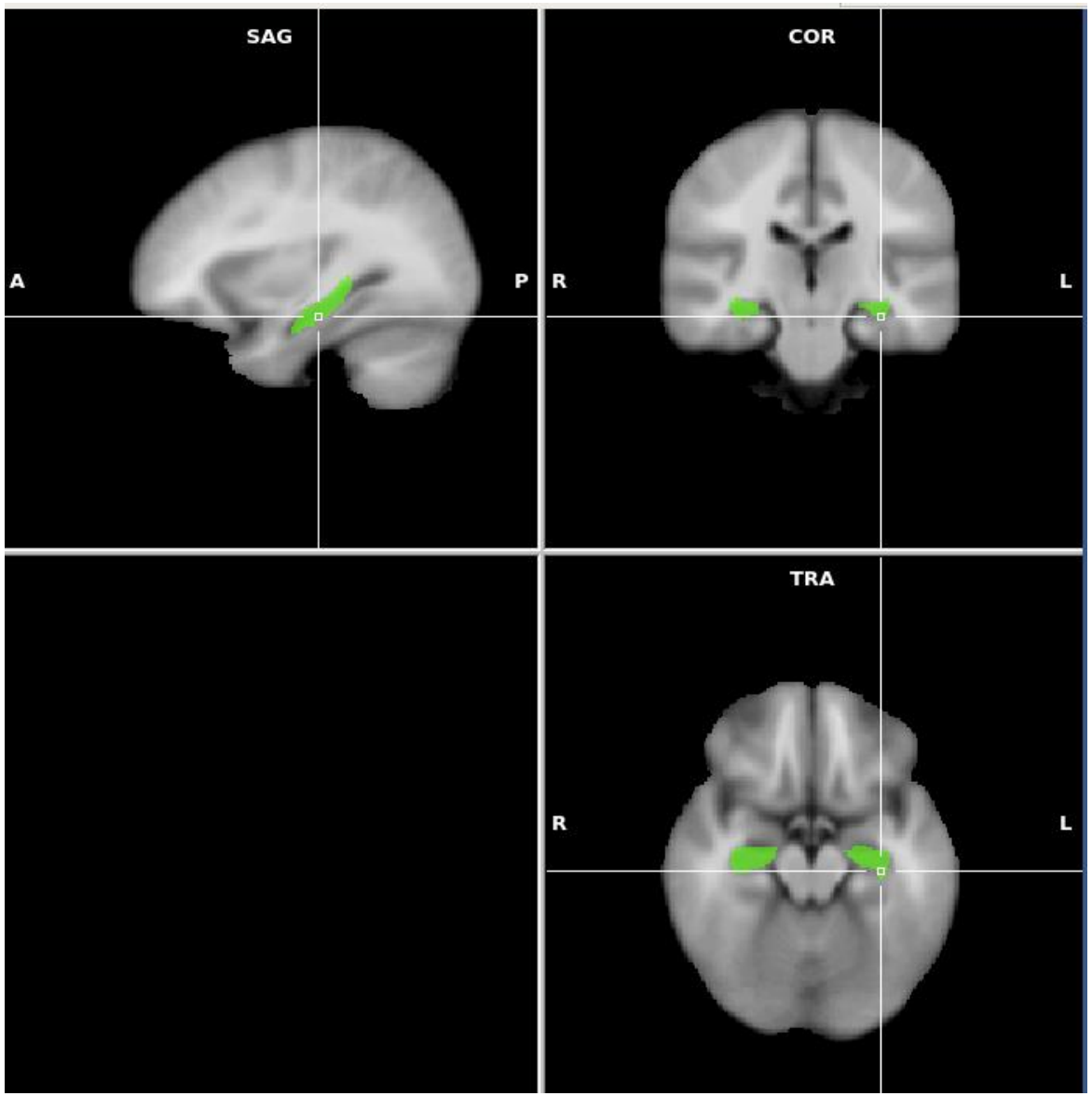
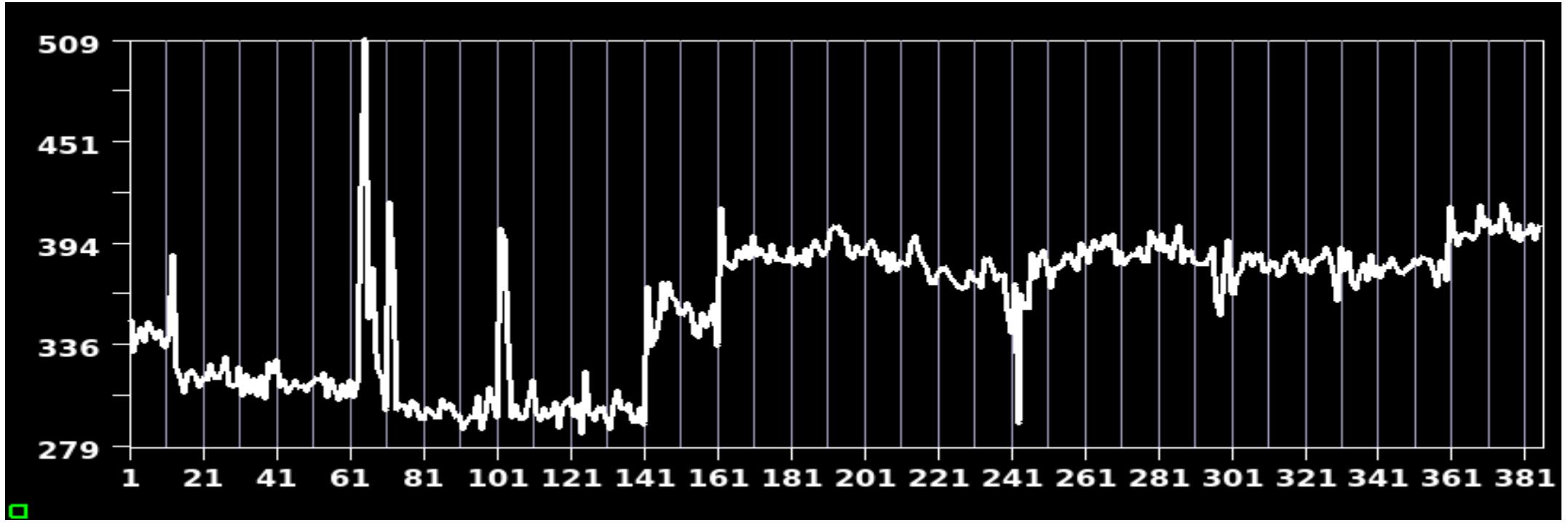


Time Course Graph



150	151	152	153	154	149	150	150	151	151
93	93	93	93	93	94	94	94	94	94
133	133	133	134	134	133	132	133	131	132
262.67	262.67	262.67	289.48	289.48	271.29	259.17	259.17	259.17	259.17
266.54	266.54	266.54	284.34	284.34	272.05	261.05	261.05	261.05	261.05
266.49	266.49	266.49	287.36	287.36	271.76	258.06	258.06	258.06	258.06
263.81	263.81	263.81	290.07	290.07	277	258.51	258.51	258.51	258.51
265.94	265.94	265.94	295.81	295.81	280.03	263.4	263.4	263.4	263.4
262.62	262.62	262.62	289.57	289.57	277.6	261.78	261.78	261.78	261.78
261.37	261.37	261.37	287.68	287.68	269.41	258.4	258.4	258.4	258.4
267.62	267.62	267.62	289.04	289.04	270.35	256.67	256.67	256.67	256.67
263.5	263.5	263.5	287.79	287.79	272.66	259.51	259.51	259.51	259.51
265.94	265.94	265.94	295.31	295.31	275	266.78	266.78	266.78	266.78
266.65	266.65	266.65	290.48	290.48	275.8	263.93	263.93	263.93	263.93
266.2	266.2	266.2	288.81	288.81	277.8	262.98	262.98	262.98	262.98

Matrix of Voxel Intensities

Machine Learning

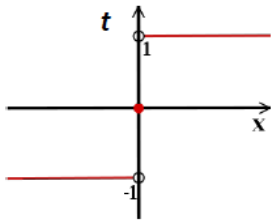
Support Vector Machines (SVMs)

- Standard SVM uses linear decision boundary given by: $\mathbf{w}^T\mathbf{x}_{new} + b$
- SVM ***decision function*** for test point:

$$t_{new} = \text{sign}(\mathbf{w}^T\mathbf{x}_{new} + b)$$

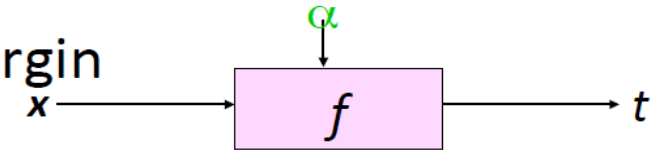
labels are $\{1, -1\}$ rather than $\{0, 1\}$

$$\text{sgn}(x) := \begin{cases} -1 & \text{if } x < 0, \\ 0 & \text{if } x = 0, \\ 1 & \text{if } x > 0. \end{cases}$$

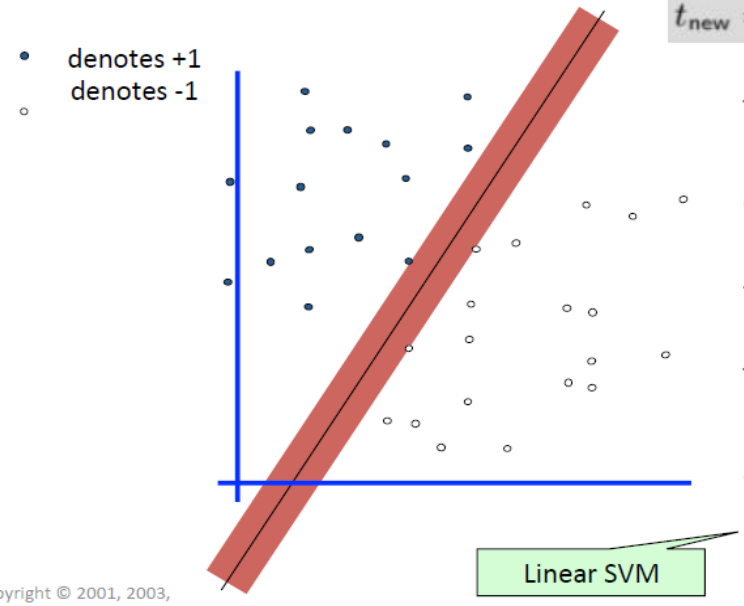


- **Goal**: find **w** and *b* based on training data
- **Criteria**: Maximize the ***margin***

Maximum Margin



$$t_{new} = \text{sign}(\mathbf{w}^T\mathbf{x}_{new} + b)$$



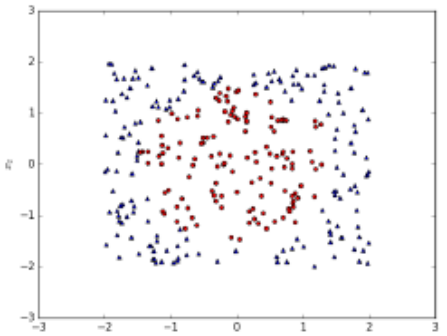
The maximum margin linear classifier is the linear classifier with the, um, maximum margin.
This is the simplest kind of SVM (Called an LSVM)

Kernels: Transforming Data

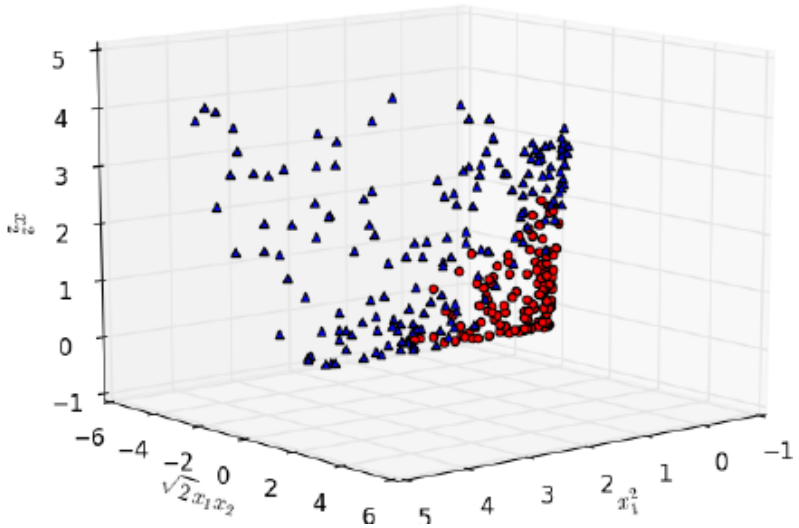
- Another example! $k(\mathbf{x}, \mathbf{z}) = \left(\mathbf{x}^\top \mathbf{z}\right)^2$

input space:
$\mathbf{x} = (x_1, x_2)^\top$

$$
\begin{aligned}
k(\mathbf{x}, \mathbf{z}) = \left(\mathbf{x}^\top \mathbf{z}\right)^2 &= (x_1 z_1 + x_2 z_2)^2 \\
&= x_1^2 z_1^2 + \sqrt{2} x_1 z_1 \sqrt{2} x_2 z_2 + x_2^2 z_2^2 \\
&= \left(x_1^2, \sqrt{2} x_1 x_2, x_2^2\right) \left(z_1^2, \sqrt{2} z_1 z_2, z_2^2\right)^\top \\
&= \phi(\mathbf{x})^\top \phi(\mathbf{z})
\end{aligned}
$$



$$\phi(\mathbf{x}) = \left(x_1^2, \sqrt{2} x_1 x_2, x_2^2\right)^\top$$



Features

Since we are dealing with Temporal Data

- Average across time
- Variance across time
- Roll out the Time Vs Intensity matrix into a single vector

Other features to consider:

- Histogram of intensities

Scaling

Feature standardization makes the intensity values at each voxel have zero mean and unit variance.
Do we do this for every voxel? Region? Or the entire Brain?

Feature	VOI	Linear	Polynomial (d=3)	RBF
All Data	All Regions	**63.4**	57.5	50.2
	Hippocampus	50.2	**60.2**	57.5
	Amygdala	**57.5**	52.5	53.2
	Thalamus	49.6	52.3	52.3
Average	All Regions	**56.4**	53.2	51.6
	Hippocampus	50.7	53.9	55.8
	Amygdala	55.8	53.9	50.4
	Thalamus	46.8	50.1	52.1
Variance	All Regions	**56.4**	53.2	53.2
	Hippocampus	53.2	53.9	55.7
	Amygdala	55.8	53.9	55.7
	Thalamus	46.8	50.1	52.1

Prediction accuracies for support vector machine classifier for different kernels, features and sub-cortical regions under consideration

Feature	VOI	Linear	Polynomial (d=3)	RBF
Average	All Regions	62.37	67.52	64.98
	Hippocampus	57.73	**70.10**	69.58
	Amygdala	61.85	68.04	63.91
Variance	All Regions	**63.91**	56.18	56.18
	Hippocampus	60.31	56.18	56.18
	Amygdala	57.73	56.18	56.18

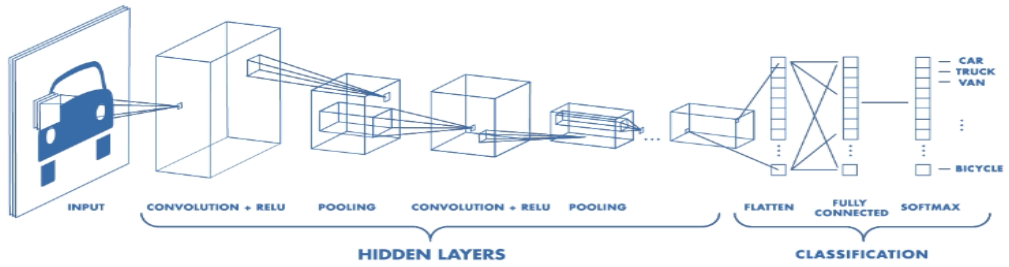
Experiential choices: Prediction accuracies for support vector machine classifier for different kernels, features with Hippocampus region under consideration

Feature	VOI	Linear	Polynomial (d=3)	RBF
Average	All Regions	62.37	67.52	64.98
	Hippocampus	57.73	**70.10**	69.58
	Amygdala	61.85	68.04	63.91
Variance	All Regions	**63.91**	56.18	56.18
	Hippocampus	60.31	56.18	56.18
	Amygdala	57.73	56.18	56.18

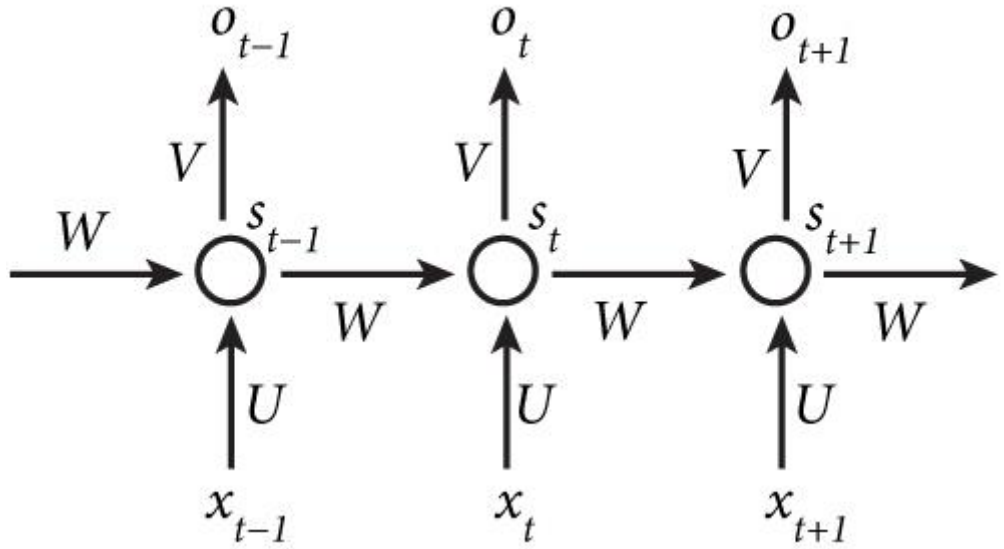
Monetary choices: Prediction accuracies for support vector machine classifier for different kernels, features with Hippocampus region under consideration

Future Steps

- A 3D Convolution Neural Network (CNN)



- A Recurrent Neural Network

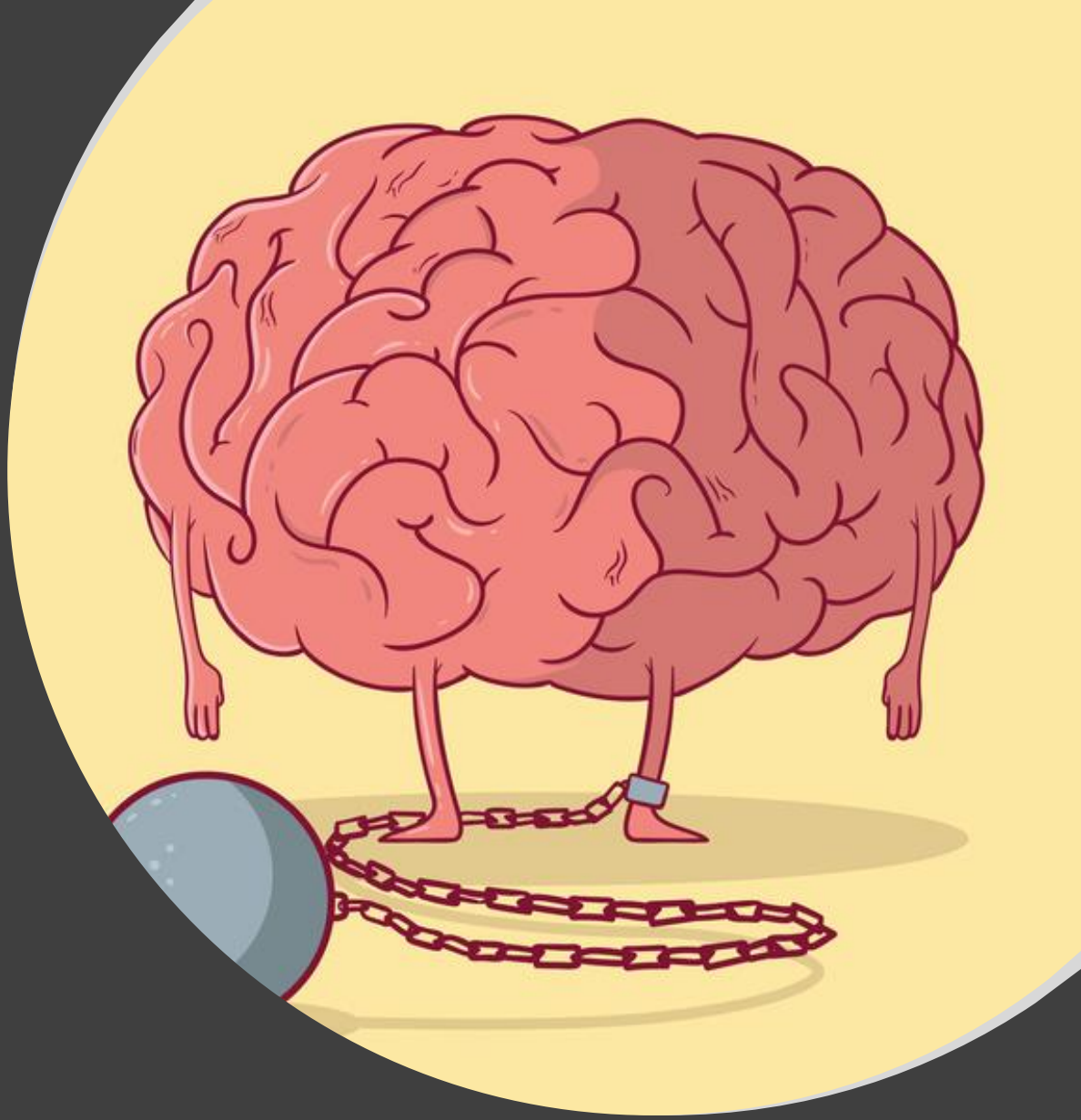


Recommendations?

- Long Short-Term Memory or Gated Recurrent Units (GRU)

Limitations

- Hemodynamic Response
- FMRI is an indirect measure of neural activity
- Noisy data
- Cross subject analysis is hard.



Thank you