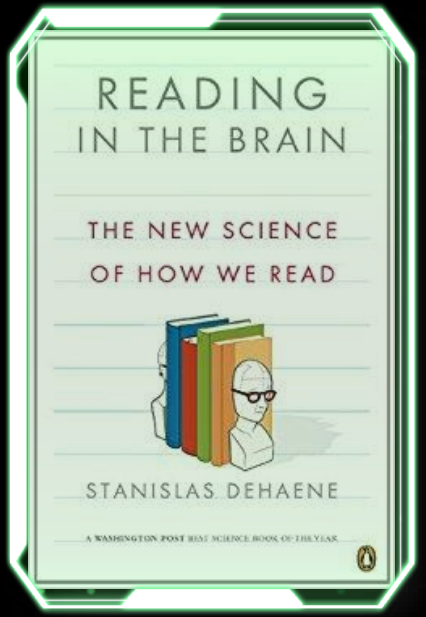

HYPERALIGNMENT
-BRAIN READING-
Yun-Fei Liu 2017-04-28

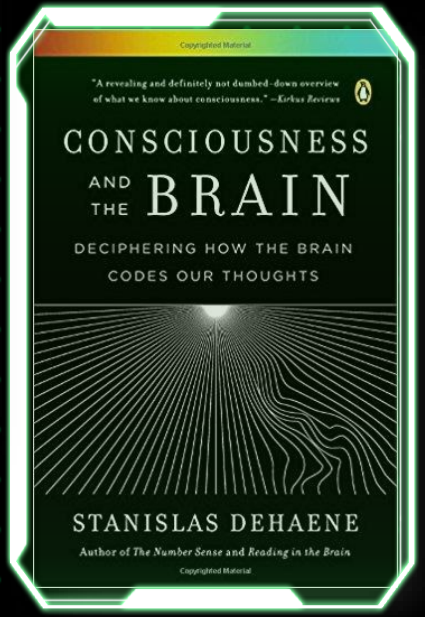
OUTLINE

- Conventional Experiment Design
  - How did cognitive neuroscientists study the brain
- Inter-Subject Correlation (ISC)
  - A data-driven method beyond the convention
- Multi-Variate Pattern Analysis (MVPA)
  - A practical method that seeks to realize BCI
- Procrustes Transform
  - How this mathematical tool deal with problems faced by ISC & MVPA
- Hyperalignment and beyond
  - Several interesting experiment results and their implications

CONVENTIONAL EXPERIMENT DESIGN

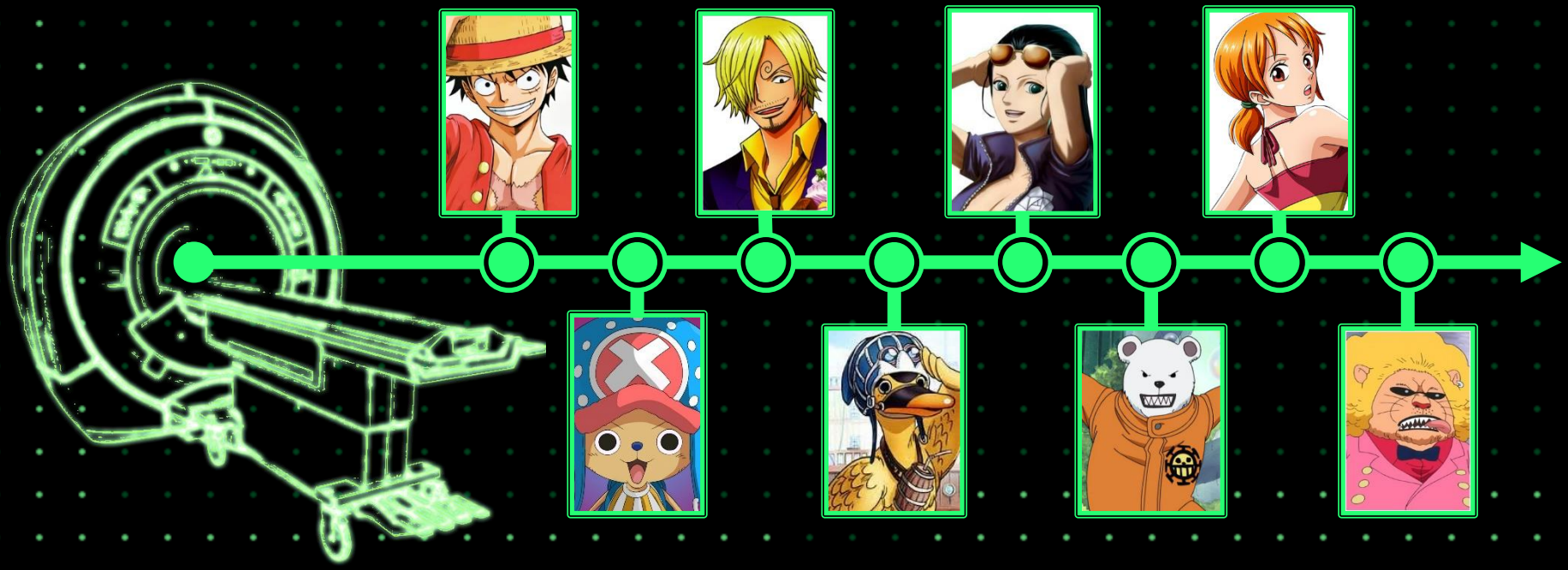
YOU MIGHT HAVE READ THESE BOOKS





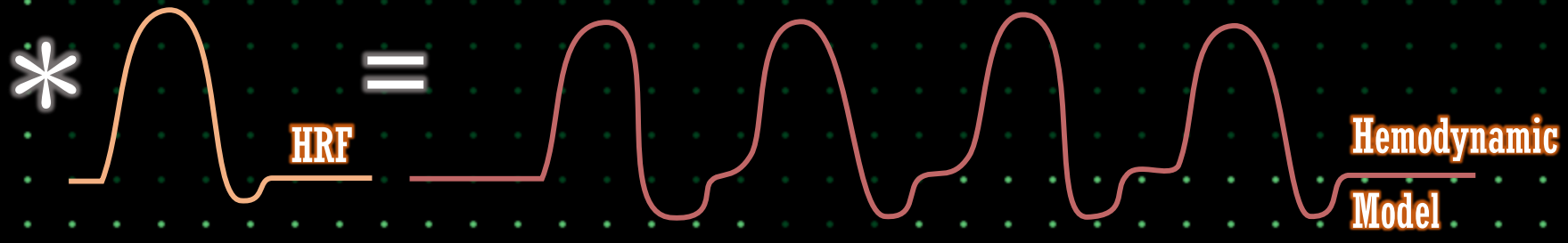
CENTRAL MOTIF

- An event takes place
- Which brain area(s) respond to this event?
- Which response(s) are selective to this event?



HEMODYNAMIC RESPONSE FUNCTION

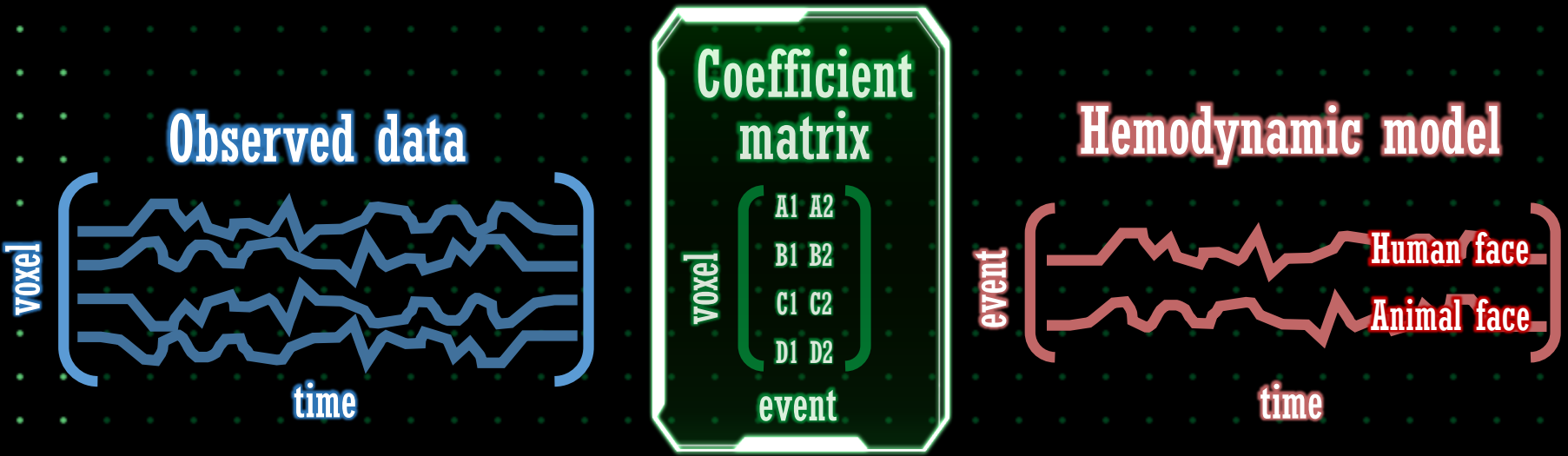
Neuronal response
(Theoretical)



GENERAL LINEAR MODEL

$$Y = AX + B$$

Error terms



INTER-SUBJECT CORRELATION

BRIEF DESCRIPTION

- Analyze neural response to natural stimuli
- Which brain region(s) exhibit a similar response waveform across all subjects?
- Steps:
  - Record neural response while subjects are receiving natural stimuli (movie, audio narrative, etc.)
  - Average the response time course at each voxel across subjects
  - For each subject, calculate the Pearson correlation between the subject's data and the average at each voxel.
  - Apply GLM to the correlation coefficient, not the waveform.
  - Do the statistics to find out voxels with significant correlation.

HOW SIMILAR ARE THE WAVEFORMS

Voxel1

Voxel2

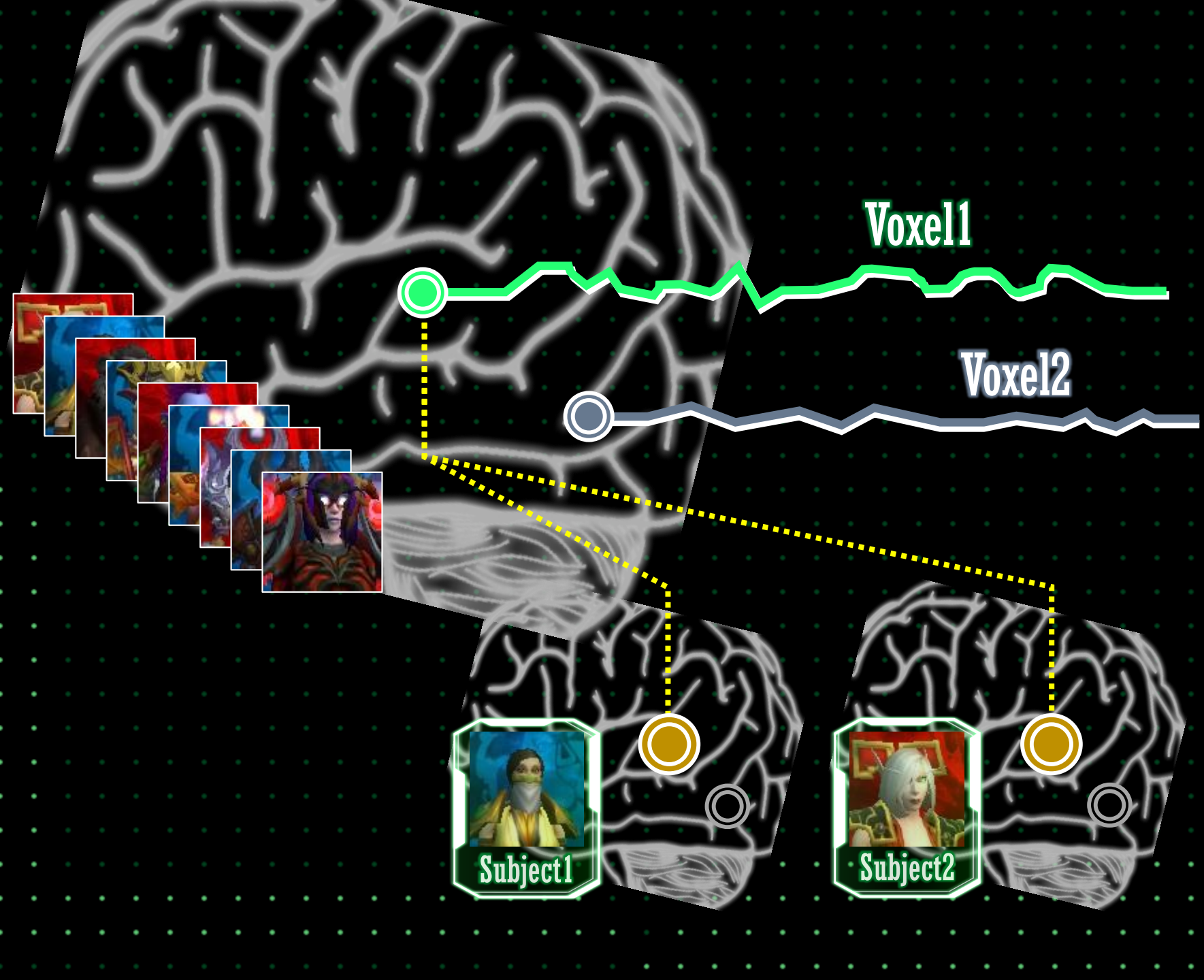
Voxel1

Voxel2

Voxel1

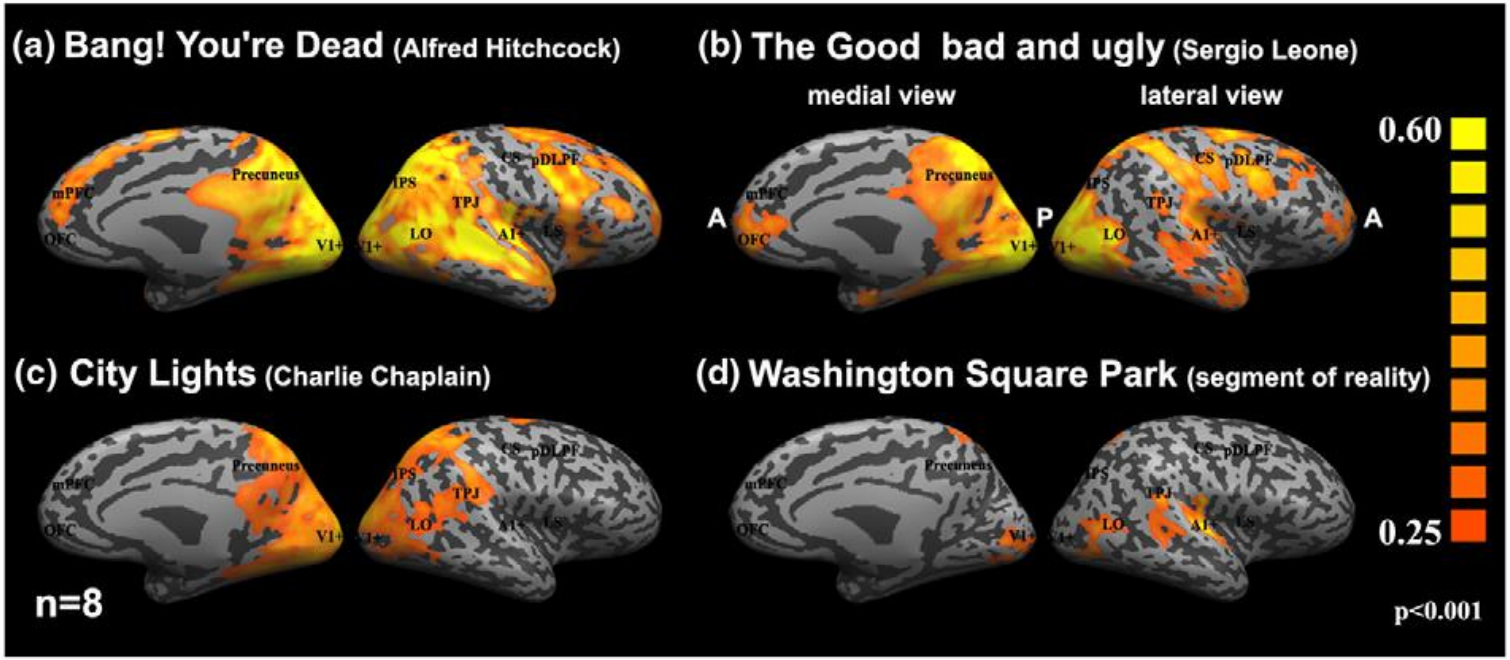
Voxel2

> 1 minute


Voxel1
Voxel2
Subject1
Subject2

EXAMPLE 1
MOVIE VS MIME

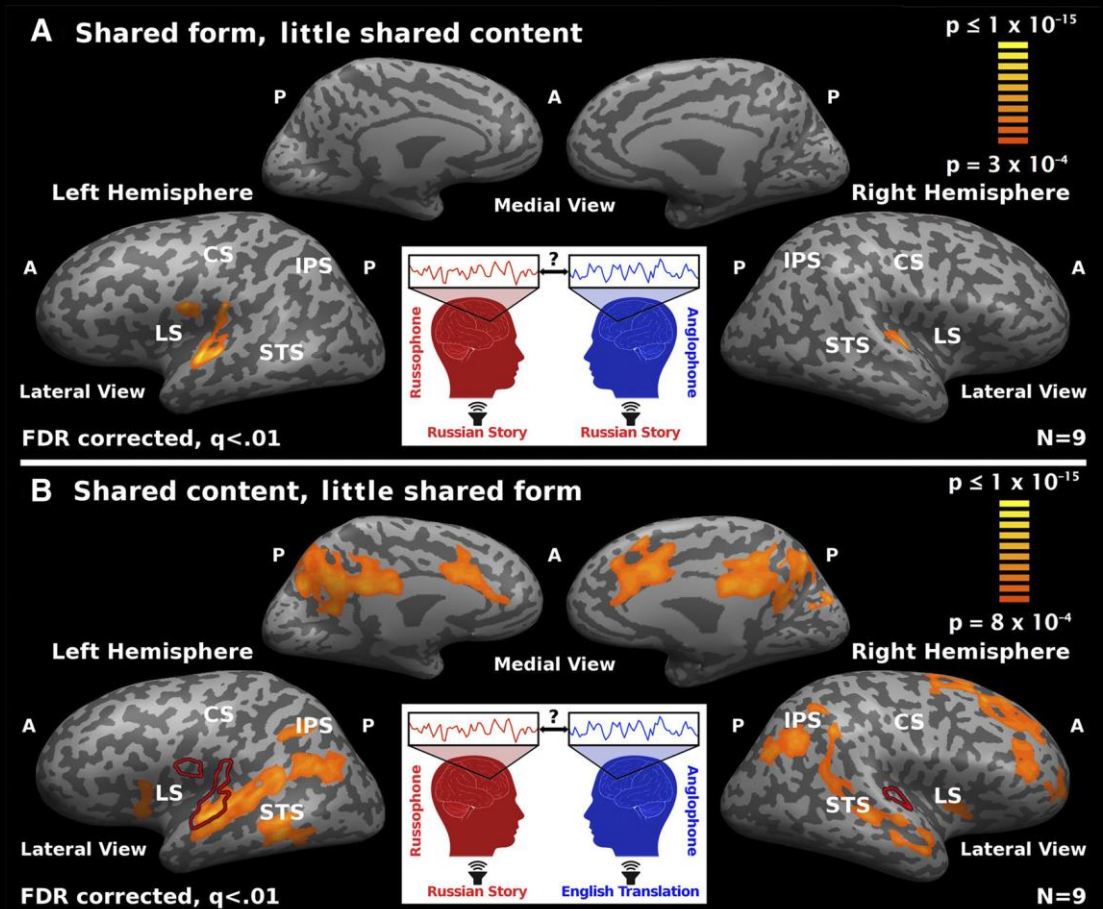
- (Hasson et al., 2010)

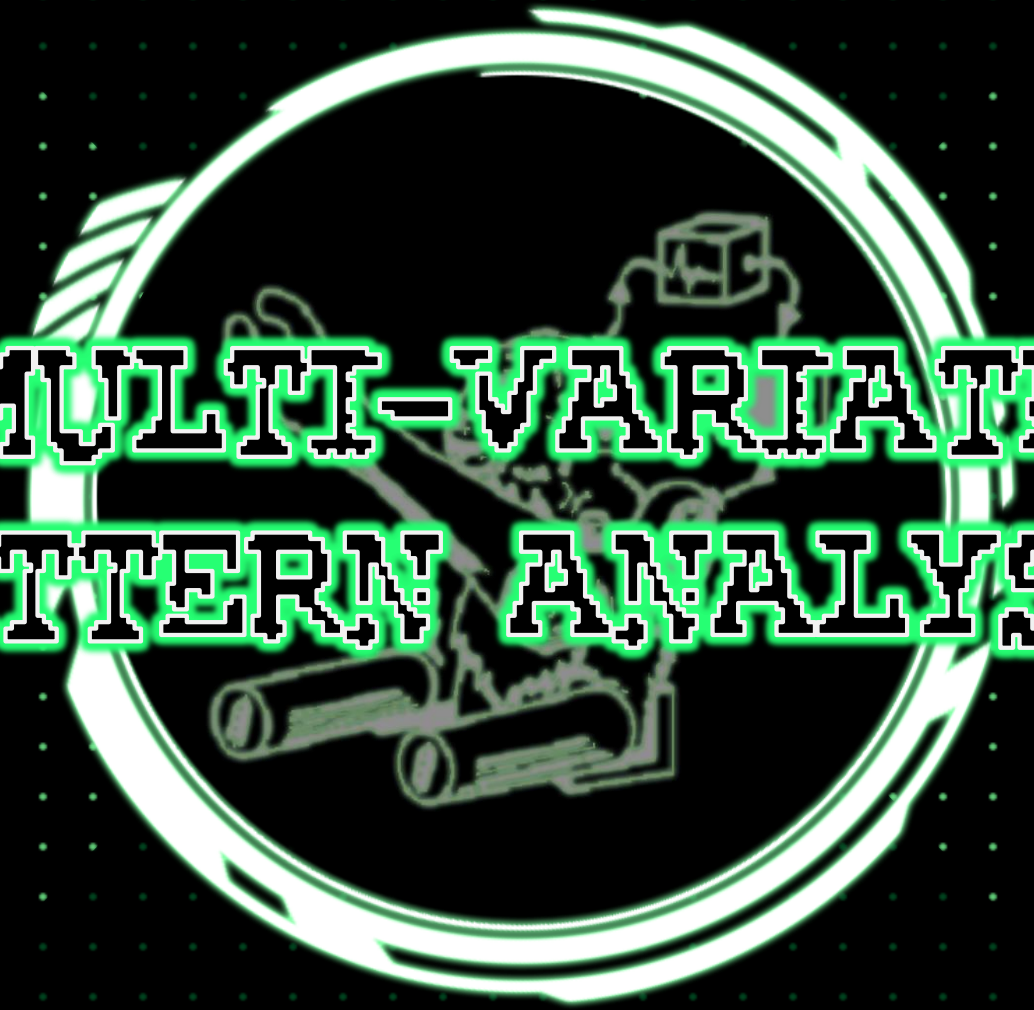


TRENDS in Cognitive Sciences

EXAMPLE 2
THE GIST OF A STORY

- (Honey et al., 2012)





MULTI-VARIATE PATTERN ANALYSIS

DECODING THE BRAIN

- When some brain areas are activated, what is the brain responding to?
- Practical value: implementing Brain Computer Interface (BCI)
- Bayesian estimation

EXAMPLE 1
IN A CAT'S EYE

- (Stanley et al., 1999)
- Electrophysiology
- Lateral geniculate nucleus (LGN)

EXAMPLE 2
THE MONUMENTAL KICK

- Miguel Nicolelis
- 2014 soccer world cup, Brazil
- More than motor control: the exoskeleton can even send sensory feedback to the brain!
- To learn more → → → → → →

EXAMPLE 3
WHAT DID YOU SEE

- (Nishimoto et al., 2011)
- fMRI, human
- Steps:
  - Watch several hours of videos
  - Build a pattern-to-scene dictionary
  - Watch new videos, record the brain activity
  - Randomly download videos from YouTube, use the dictionary to predict the brain activity evoked by these videos.
  - Average the top 100 videos whose predicted activities are the most similar to the observed data.

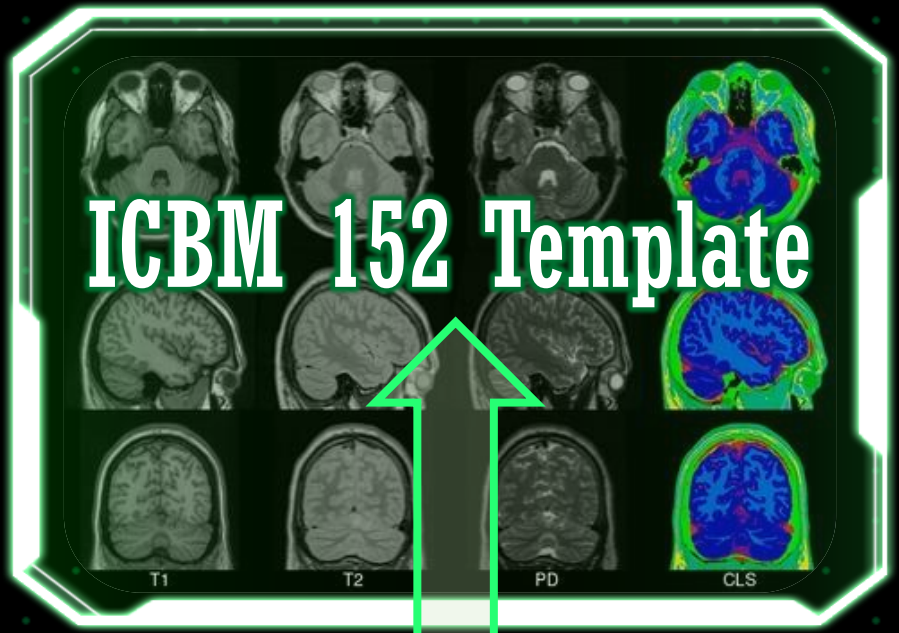

PROCRUSTES TRANSFORM
AND HYPERALIGNMENT

WHO ARE THE SUBJECTS

- ECoG, implanted electrode, other invasive methods:

- If not invasive……
- Are you satisfied?

MATCHING BRAIN STRUCTURES IS HARD



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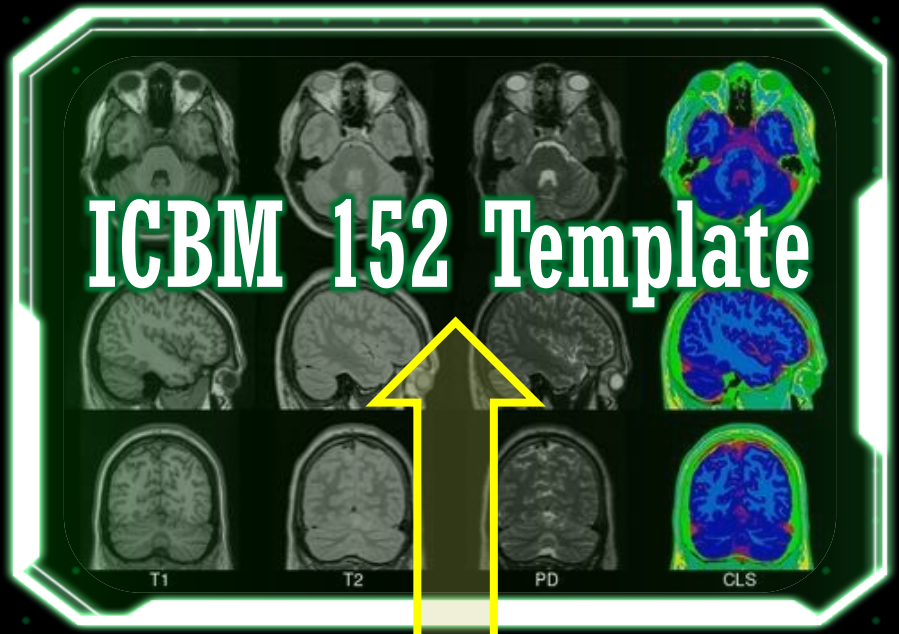
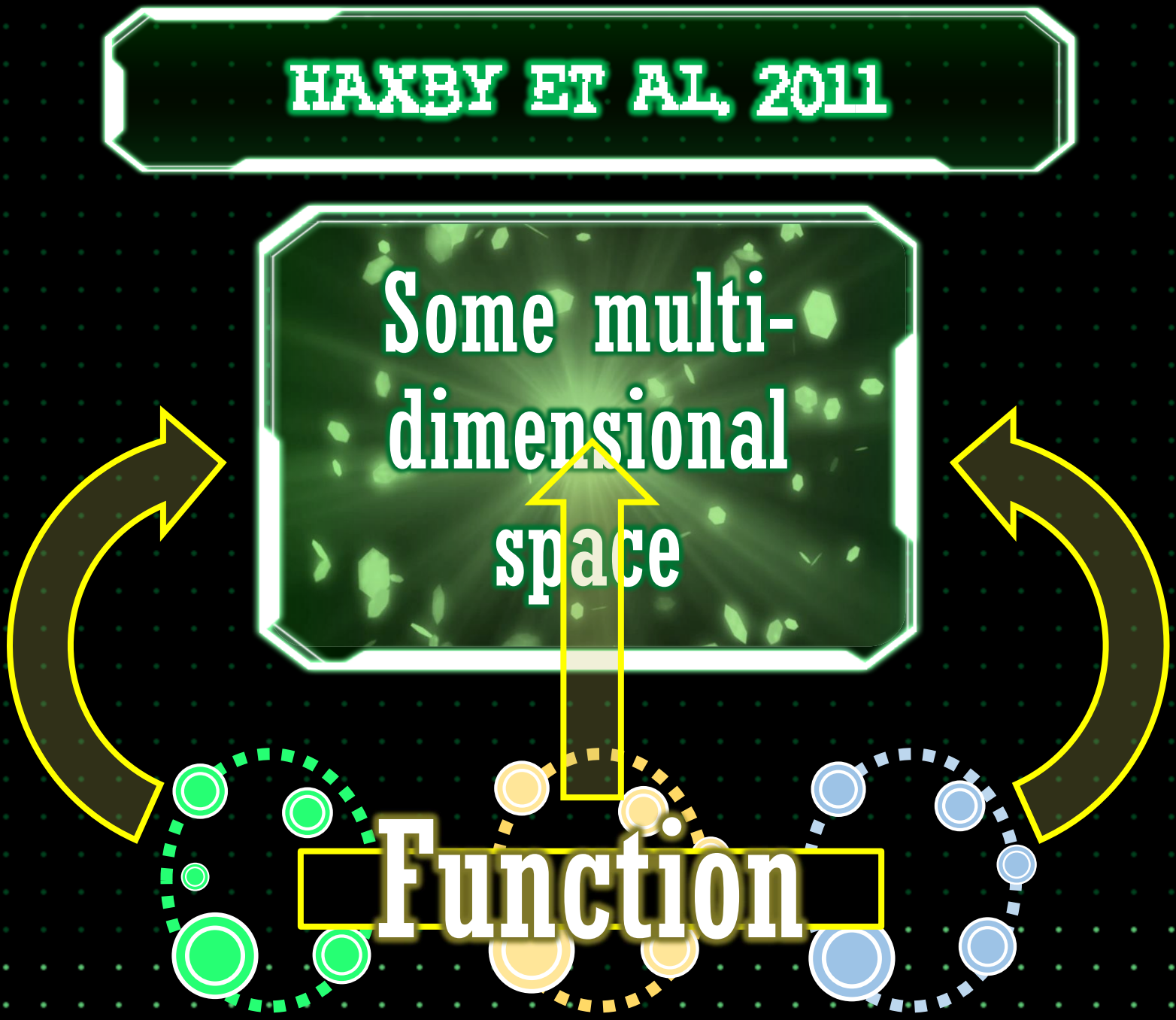
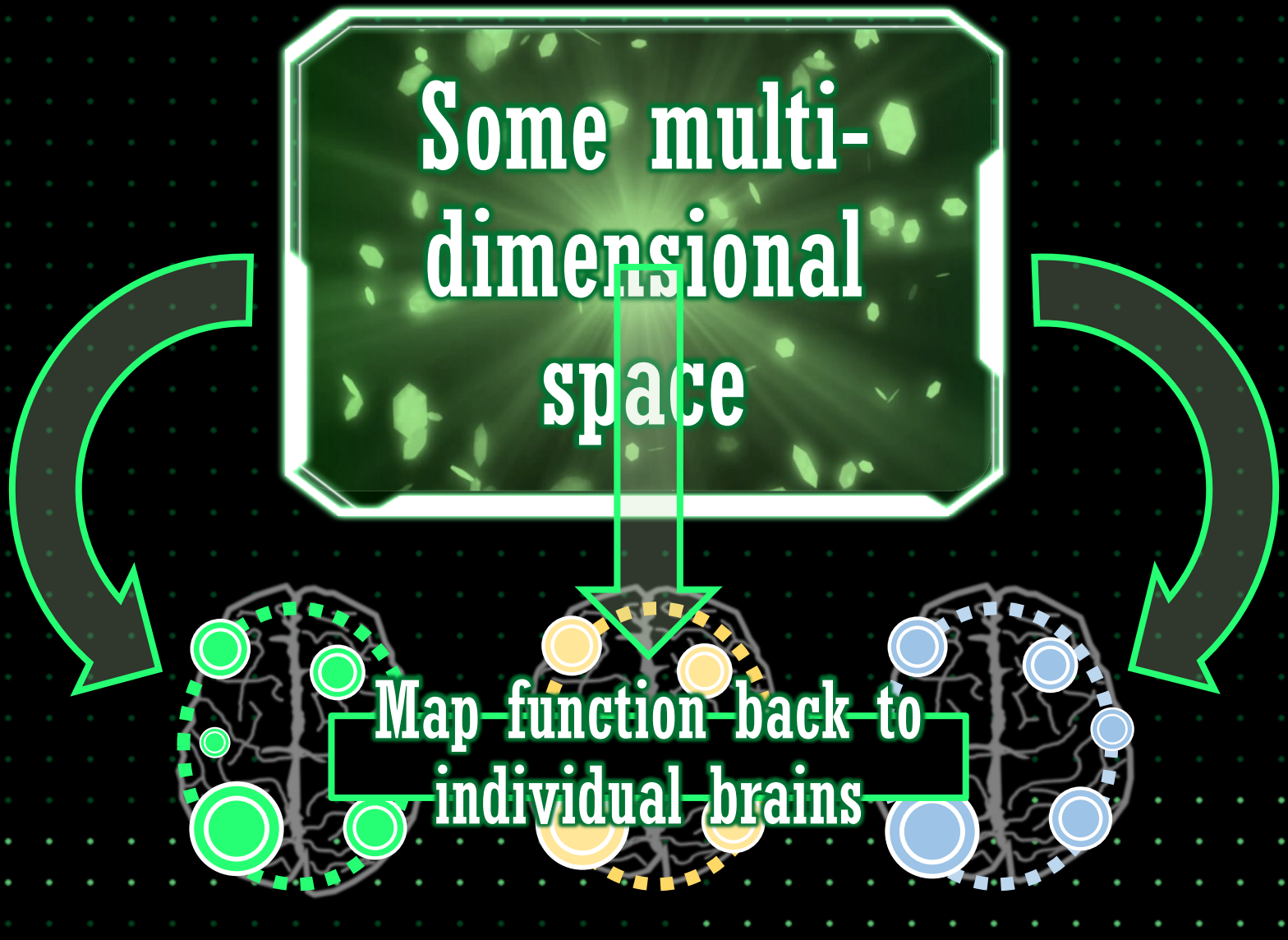



HAXBY ET AL 2011
Some multi-dimensional space
Function

HAXBY ET AL 2011



DEFINE A POINT IN THE HYPERSPACE

	Voxel 1	2	3	4	5	6
• Event 1	4	3	2	2	6	7
• Event 2	2	5	4	3	4	5
• Event 3	4	4	2	5	6	3

MORE POINTS

- As many events = points as possible!
- As many voxels involved as possible!
- Natural stimuli ……MOVIE!!

THE MATRIX EQUATION

$$B = AT + E$$

Dimensions

Time points

Voxels

Time points

Map to the hyperspace

ORTHOGONAL PROCRUSTES PROBLEM

$$B = AT + E$$

$$\vdash TT' = T'T = I$$

$$\llcorner \operatorname{trace}(E'E) = \min$$

PROCRUSTES

- Idiom:

Procrustean bed

METHOD TO FIND SOLUTION TO PROCRUSTES PROBLEM

- For detailed deduction, please refer to (Schönemann, 1966)

$$B = AT + E$$

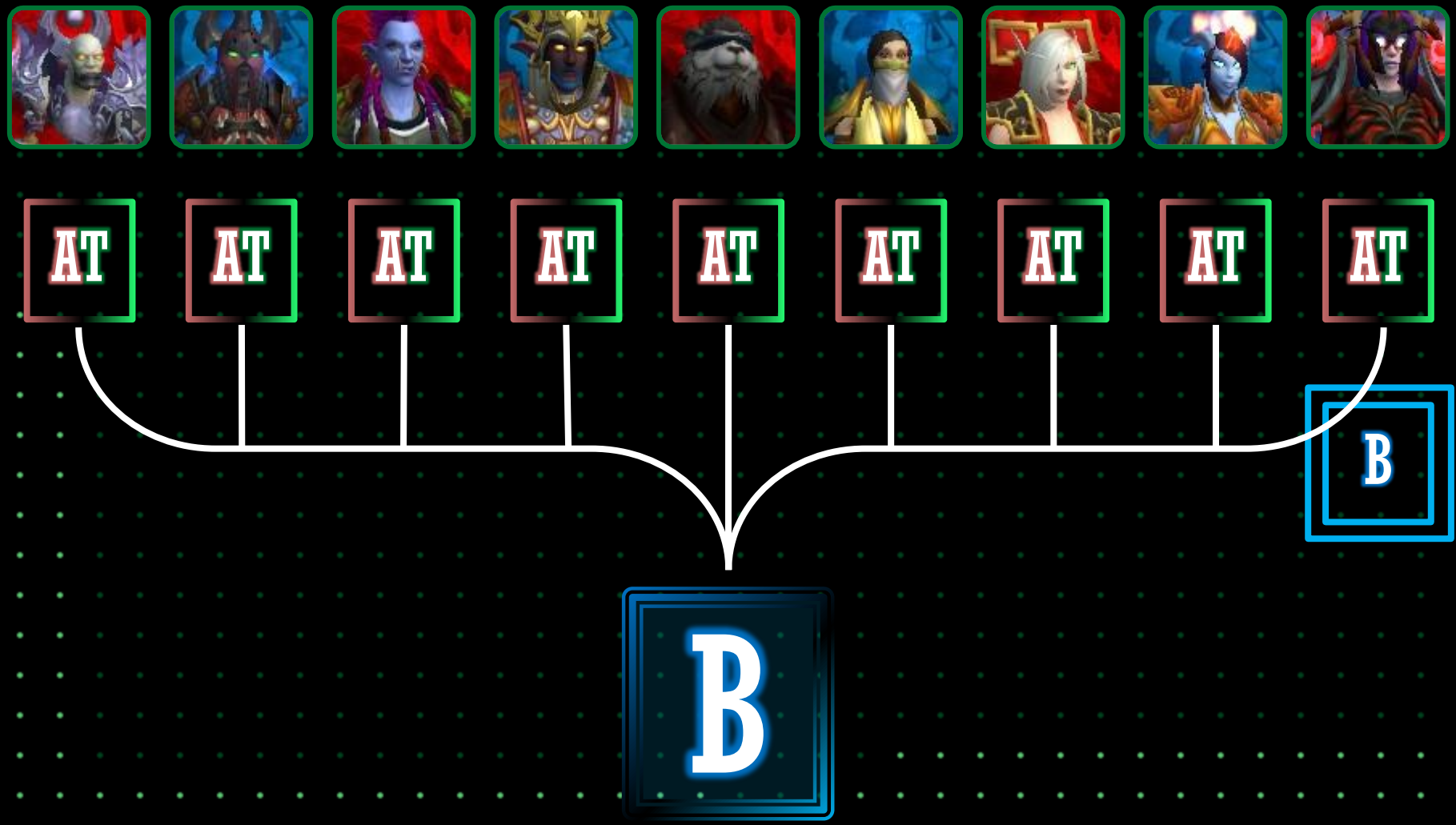
MATLAB implementation:

[d, z, T] = procrustes(B, A)

1. Get A and B
2. Compute S = A'B
3. Diagonalize:
   S'S = VDV'
   SS' = WDW'
4. T = WV'

BUT WHAT IS THE B MATRIX

BUT WHAT IS THE B MATRIX



BUT WHAT IS THE B MATRIX

T T T T T T T T T

From now on, use the T's to map new functional image to B to analyze, and use (T')s to map results back to individual brains.

B

HYPERALIGNMENT AND BEYOND

HAXBY ET AL. 2011

A

- Response to half of the movie (2205 time points)
- 1000 voxels (ventral temporal regions, VT)

- Response to stationary pictures

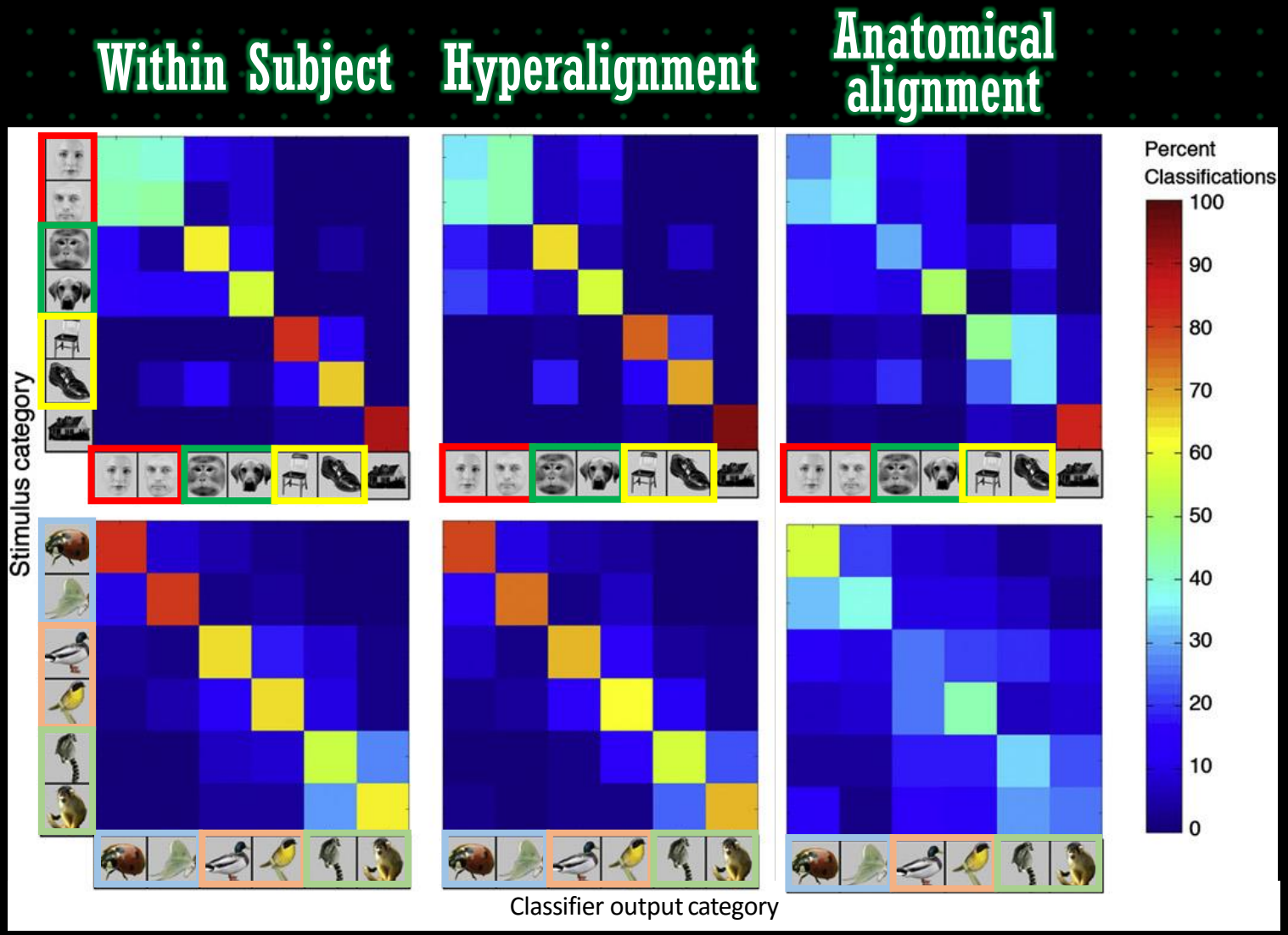
T

B

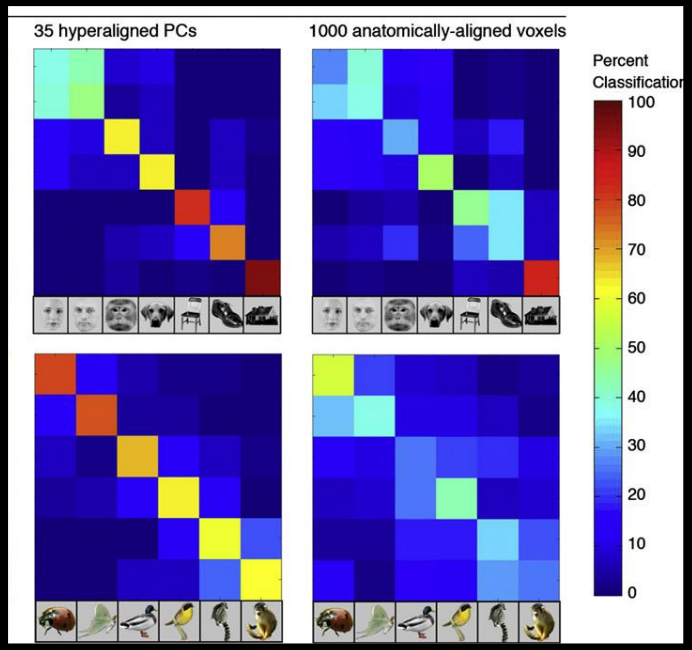
- 1000 dimensions

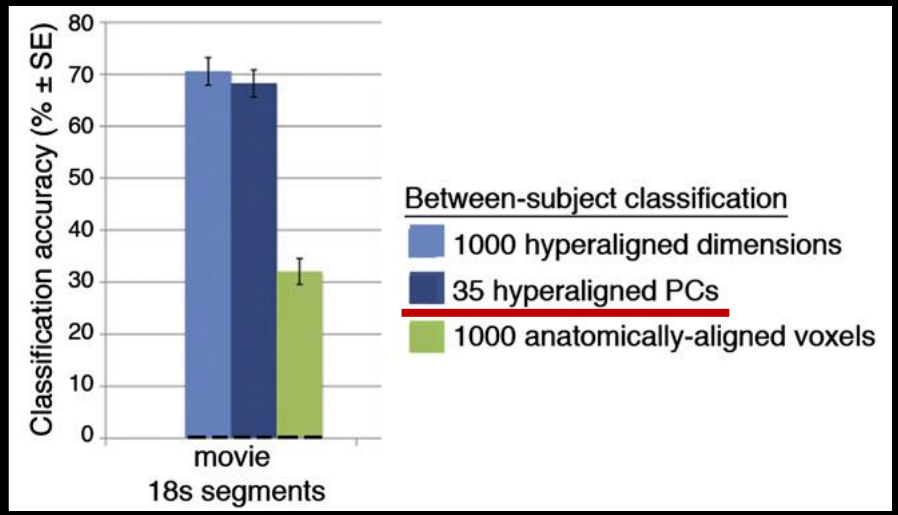
Then, try to classify them!

CATEGORICAL CLASSIFICATION



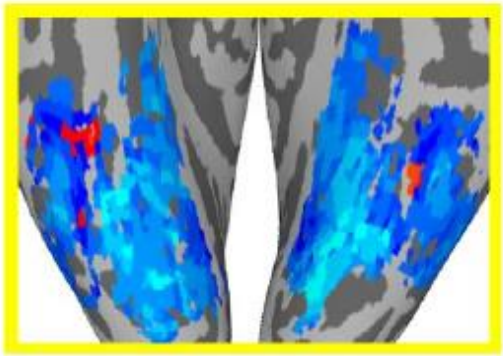
MOVIE TIME SEGMENT CLASSIFICATION

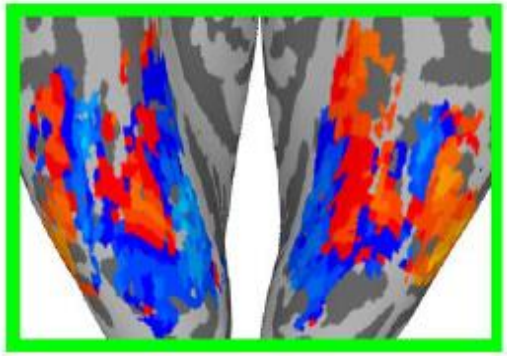




Principal component analysis

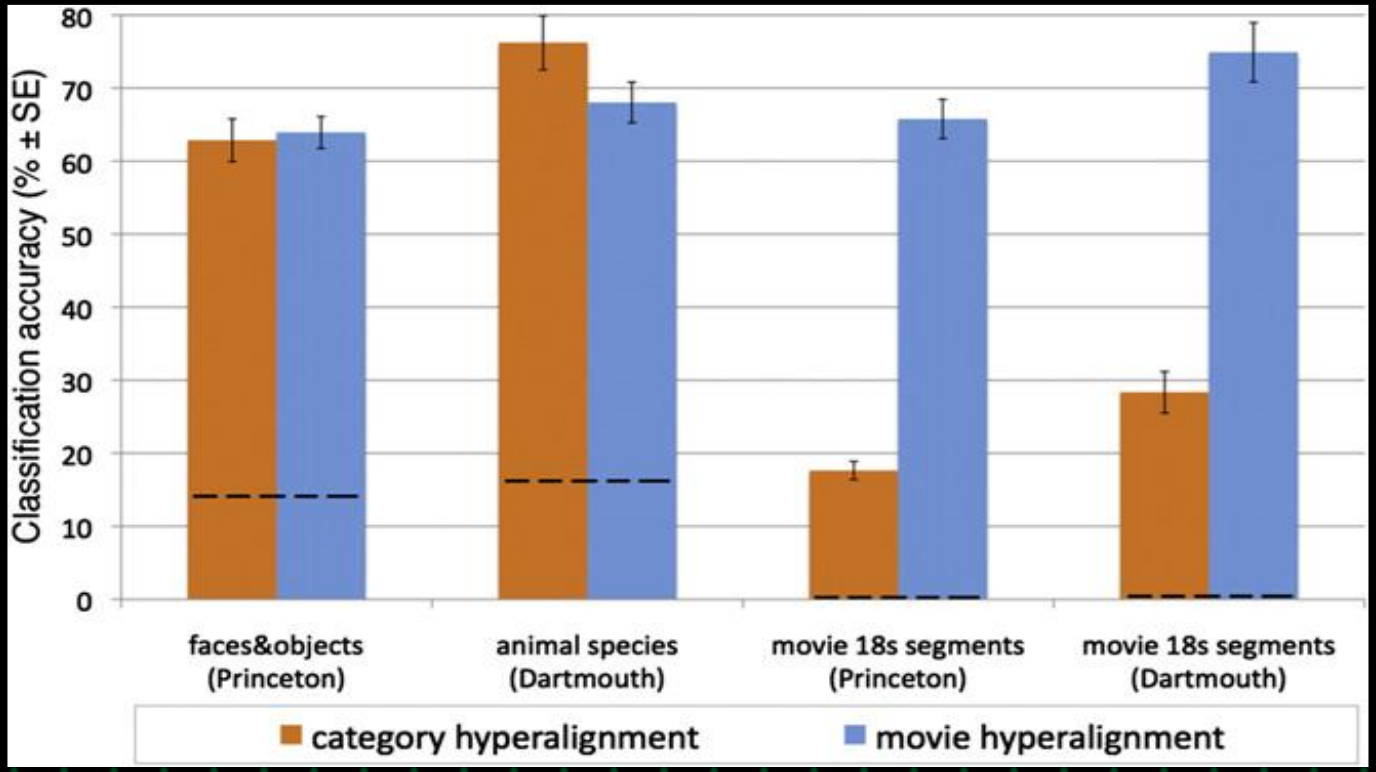
P		Principal components				
		pc_1	pc_2	pc_3	...	pc_{35}
Voxels	v_1	$w_{1,1}$	$w_{2,1}$	$w_{3,1}$	...	$w_{35,1}$
	v_2	$w_{1,2}$	$w_{2,2}$	$w_{3,2}$	...	$w_{35,2}$
	v_3	$w_{1,3}$	$w_{2,3}$	$w_{3,3}$	...	$w_{35,3}$
	...	...	...	...		...
	v_{1000}	$w_{1,1000}$	$w_{2,1000}$	$w_{3,1000}$	...	$w_{35,1000}$





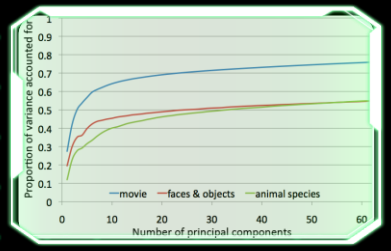
TRY USING SIMPLE STIMULI TO ALIGN

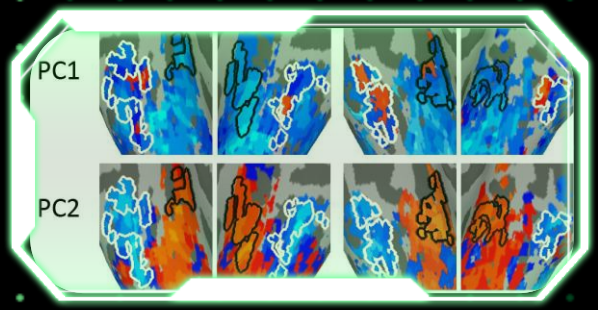
- Movie VS all the stationary pictures

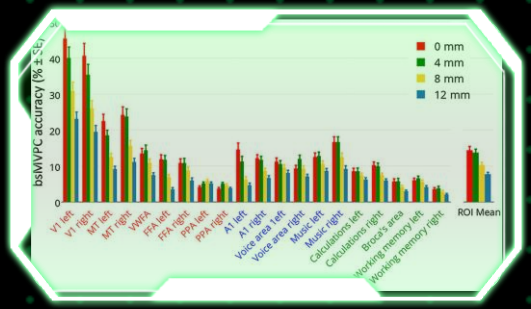


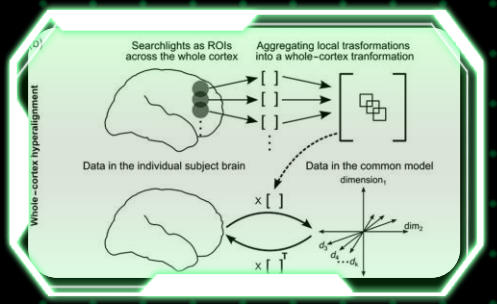
MORE TO GO

- How many PCs are enough? Voxels?
- Map the PCs back to individual brains?
- Effect of spatial smoothing? (Guntupalli et al., 2016)
- Whole brain analysis? (Guntupalli et al., 2016)





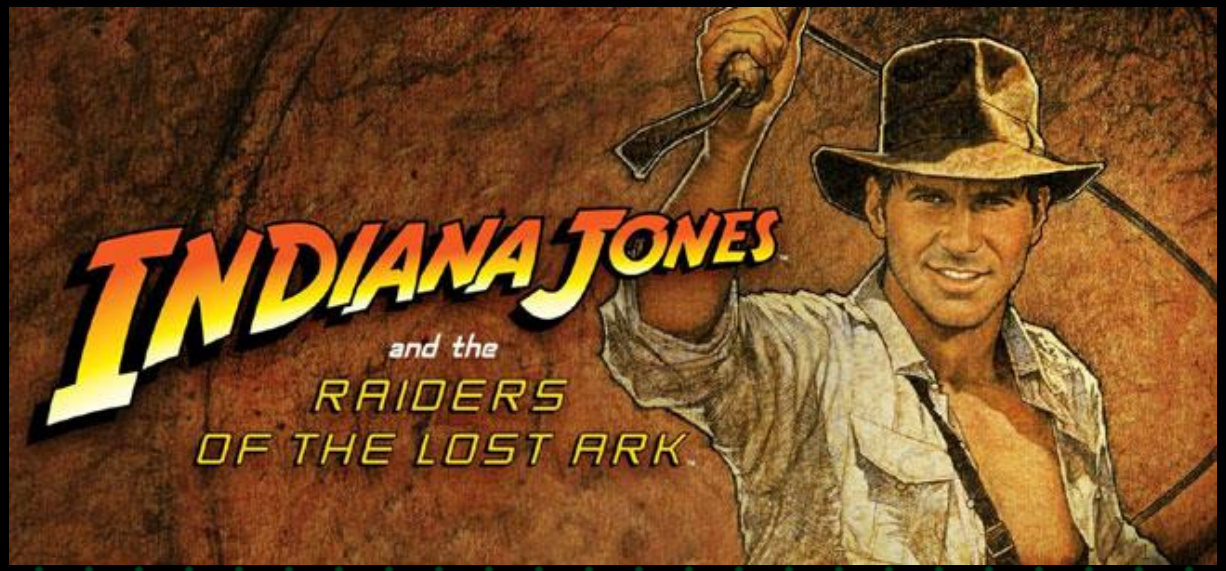




Can a UNIVERSAL and clinically valuable "gold standard" be established?

SOMEDAY.....

When you go to the hospital for a health check,
The doctor asks you to relax in the MRI scanner.
Then you hear.....



You know what's going on!

THAT'S ALL

THANK YOU!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STUDIO