# Scientific Images: Depictions/Diagrams/Data

(what we see is what we know)



M284A 9-26-2016











FIG. 4. Bode plots of mean gain and phase for regular afferents ( $\circ$ ), irregular afferents ( $\Delta$ ), all afferents ( $\times$ ), and second-order neurons ( $\bullet$ , from data of Refs. 15 and 23). For the second-order neurons, phase was derived from 32 neurons, gain from 26. Error bars show standard deviation for second-order neurons and for population of all afferents. Sensitivity normalized at 0.175 Hz for afferents, 0.19 Hz for second-order neurons.



### afferents ( $\circ$ ), irregular afferents ( $\triangle$ ), all afferents ( $\times$ ),



FIG. 4. Bode plots of mean gain and phase for regular afferents ( $\bigcirc$ ), irregular afferents ( $\triangle$ ), all afferents ( $\times$ ), and second-order neurons ( $\bullet$ , from data of Refs. 15 and 23). For the second-order neurons, phase was derived from 32 neurons, gain from 26. Error bars show standard deviation for second-order neurons and for population of all afferents. Sensitivity normalized at 0.175 Hz for afferents, 0.19 Hz for second-order neurons.



Figure 2. Camera lucida drawings of apical dendrites partially depicted in Figure 1. The *arrows* indicate the same dendritic spines indicated in Figure 1. Scale bar,  $10 \ \mu m$  for both A and B.



Figure 3. Number of dendritic spines per  $10-\mu m$  dendrite obtained from apical portion of CA1 pyramidal cell dendritic tree. Values represent means + SEM. The *asterisk* denotes a significant difference from proestrus (p < 0.01).

Woolley, et al., J Neurosci. 10:4035, **1990** 



VJ Wedeen diffusion tractography 2011

# • What do images have in common?

elements of a general science of imaging

-[increasingly, images are data

— commonalities: quantization, resolution, dimension reduction, feature detection, distortion, semiotics, analysis, perception, noise, compression, presentation, repeated measures, sensitivity uniformity, motion and dynamics, etc...

— stakeholders: physics, chemistry, medical imaging, astrophysics, nanoscience, mathematics, design media|arts, statistics...

#### WHAT IS AN IMAGE?

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Edited by James Elkins and Maja Naef





#### Images as a very skin of things.

#### Images as reminders.

Images as defective sign systems.







images reflect our cognitive constructs of the world. they reflect our brains and our evolutionary origins.



#### Picasso "Donna che dorme"











Culham, et al., J Neurophysiol 81, 1999





Shepard and Metzler, Science, 1971





Cohen, Kosslyn, et al., **Brain**, 1996



# I. Depictions

## II. Diagrams

Exports and Imports of SCOTLAND to and from different parts for one Year from Christmas 1780 to Christmas 1781 .

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J. von Kupferstich, Icones anatomicae, 1743



the Act diverse James 9.4 17 0.







Images from Bronskill, M. J., E. R. McVeigh, et al. 1988 *Radiology* **166**(2): 485-8.



MS Cohen and D Baird, Perspective on Science, 7(2): p. 231-254. 1999





Three Old Women Beating a Devil on the Ground Daniel Hopfer c. 1470





Gunther von Hagens ''Flayed Man'' c. 2000




































American Association for the Advancement of Science



1 NOVEMBER 1991 Vol. 254 B Pages 621–768













digital Images









superresolution weiss

# IMAGE SPARSITY

Many Images Can Be Represented Sparsely In a Different Representation or Basis (e.g., Wavelet or Fourier)



Kelly et al., Science vol.273, pg.1371 (1996).



Original 5.8 Mb



JPEG 678Kb

QUESTION: Why Acquire All of the Original Pixels When a Fraction Will Do?



## DATA STRUCTURE Redundancy or Knowledge Reduces Sampling Requirements





An MBO Scheme on Graphs for Segmentation and Image Processing Ekaterina Merkurjev, Tijana Kostic, Andrea Bertozzi (submitted) SIAM J. Imag. Proc. 2012

## computer vision



### pascal challenge 2012

## computer vision



#### pascal challenge 2012

Brain Reading / Brain Networks EEG and fMRI O Data Sparsity Image Sparsity Brain Sparsity

# FMRI

#### explores intensity variations in MR signal





#### intensity variations reflect venous [O2]

K Kwong, et al., "Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation." PNAS, 1992.





# MACHINE LEARNING IN FMRI





Haxby, et al., Science 293:2426, 2001

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# Curse of Dimensionality



# Brain Networks



## A MODEL of COGNITION

Multiple Networks are Concurrently Active

- Current Cognitive State Reflects the Contributions of all Currently Active Networks
- Many Such Networks are Common Across People
- Perhaps:

$$CS \approx \alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3 + \ldots + \alpha_j N_j.$$

Where:

CS is the current cognitive state

 $N_k$  is one among many networks

- $\boldsymbol{\alpha}_k$  is the "activity" level of the corresponding network
- $\rightarrow$  CS and  $\alpha$  are functions of time

## Brain Reading

- Given an observed series of  $\alpha_n$ , identify (classify) CS  $CS \approx \alpha_1 N_1 + \alpha_2 N_2 + \alpha_3 N_3 + \ldots + \alpha_j N_j$  $CS \approx AN + \sigma$ .
- Sparsity issues:
- ——[How Many N's (features)?
- [How Many CS's (cognitive states)?

# INDEPENDENT COMPONENTS ANALYSIS (ICA)





data are decomposed into a set of spatially-independent maps and a set of time courses.

http://www.fmrib.ox.ac.uk/fslcourse/lectures/melodic.pdf



#### The functional architecture of the human brain: Correspondence between resting FMRI and task-activation studies

Stephen M. Smith<sup>1</sup> Peter T. Fox<sup>2</sup> Karla L. Miller<sup>1</sup> David C. Glahn<sup>3,2</sup> P. Mickle Fox<sup>2</sup> Clare E. Mackay<sup>1</sup> Nicola Filippini<sup>1</sup> Kate E. Watkins<sup>1</sup> Roberto Toro<sup>4</sup> Angela R. Laird<sup>2</sup> Christian F. Beckmann<sup>5,1</sup>



## IC DICTIONARY ELEMENTS



"Categorization and Generation of group-wide independent components in fMRI using clustering." A Anderson I, J Bramen, A Lenartowicz, P Douglas, C Culbertson, A Brody, MS Cohen. OHBM 2010

# Operationalized Belief

Autobiographical

	I own a toaster oven.	Disbelieve Believe
•	Ethical	
	It is good to help people in need.	Disbelieve Believe
•	Factual	
	Sugar is sweet.	Disbelieve Believe
•	Geographical	
	Nevada borders California.	Disbelieve Believe
•	Mathematical	
	(45/3) + 25 = 40.	Disbelieve Believe
•	Religious	
	Jesus was actually born of a virgin.	Disbelieve Believe
•	Semantic	
	"Gigantic" means "Huge."	Disbelieve Believe

S Harris, et al., Annals of Neurology, 63(2) 2008.

## CLASSIFYING BELIEF AND DISBELIEF



#### **GLM** Results

S Harris, et al., Annals of Neurology, 63(2) 2008.

#### Highest Ranked ICs

PK Douglas et al., NeuroImage, 56(2): p. 544-553. 2011.

## Belief Detector

Forward Subset Selection 19 Features, Classification 80%



PK Douglas, et al., NeuroImage, 56(2): p. 544-553. 2011.

©2003 Randy Glasbergen



"I have the results of your brain scan. We found all of your computer passwords, evidence that you cheat on your taxes, and the secret place where you hide candy from your wife and kids."




## Iconic Images







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— stakeholders: physics, chemistry, medical imaging, astrophysics, nanoscience, mathematics, design media|arts, statistics...

• what does a unified theory/approach mean?

• why is this important?

• is it possible?