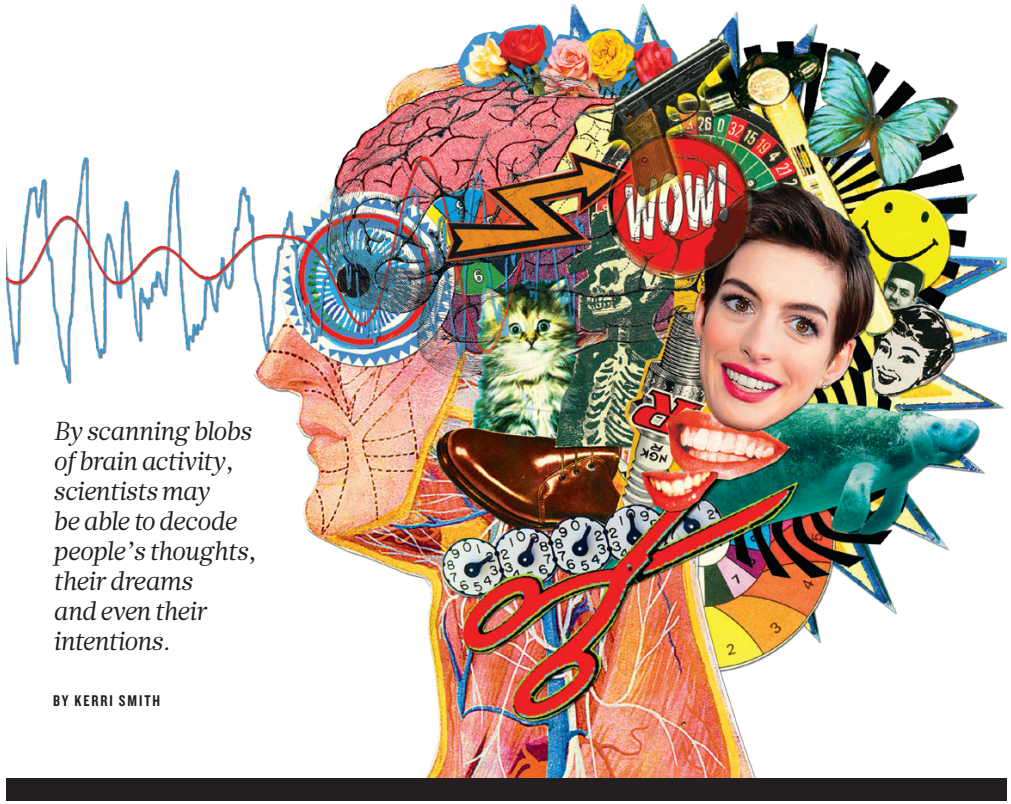
機械学習を使って
脳から夢の内容を解読する

ATR脳情報研究所
神谷之康

“Brain decoding”, “Mind-reading”



By scanning blobs of brain activity, scientists may be able to decode people's thoughts, their dreams and even their intentions.

BY KERRI SMITH

Reading minds

Jack Gallant perches on the edge of a swivel chair in his lab at the University of California, Berkeley, fixated on the screen of a computer that is trying to decode someone's thoughts.

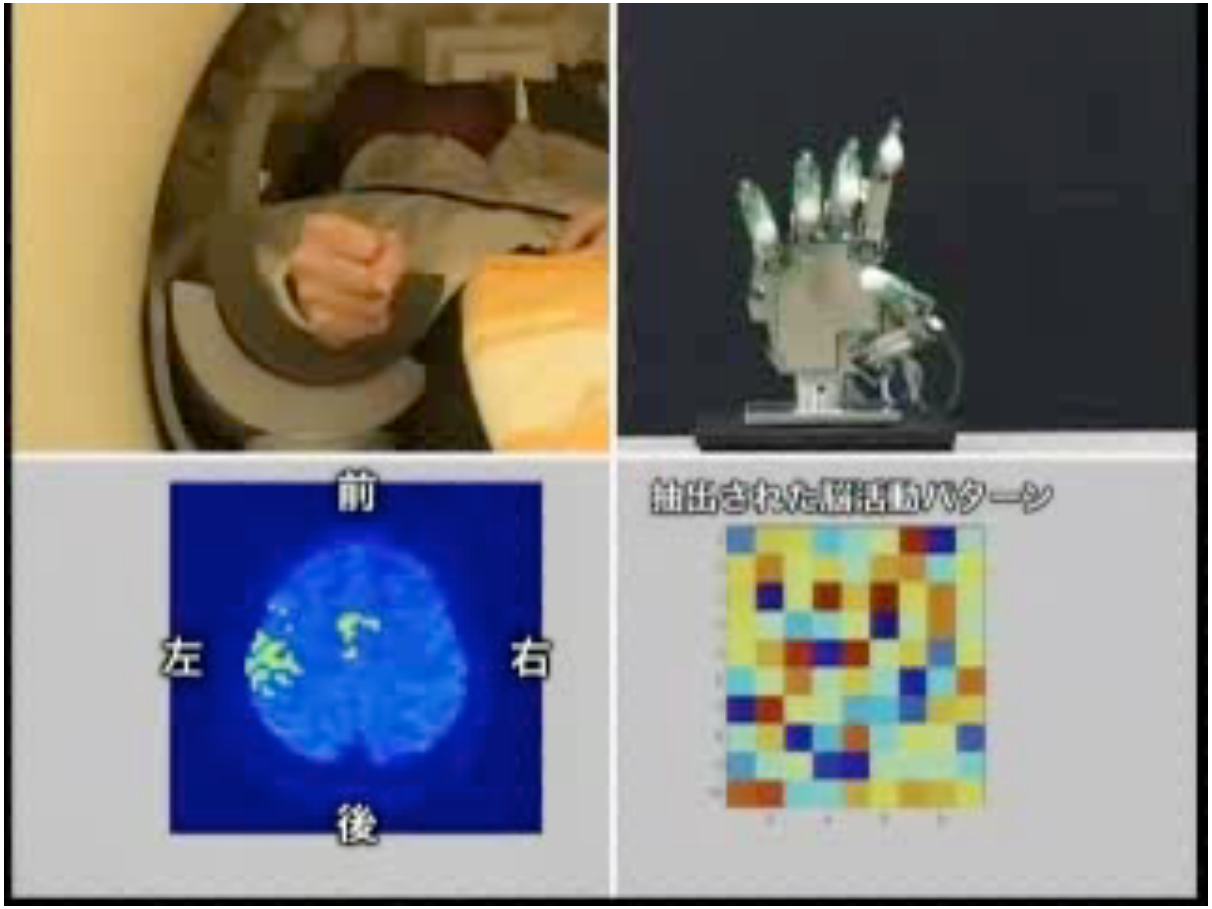
On the left-hand side of the screen is a reel of film clips that

activity elicited by a range of images and film clips. His program had encountered large aquatic mammals before, but never a manatee.

Groups around the world are using techniques like these to try to decode brain scans and decipher what people are seeing, hearing and

Nature, Vol 502, 24 October, 2013

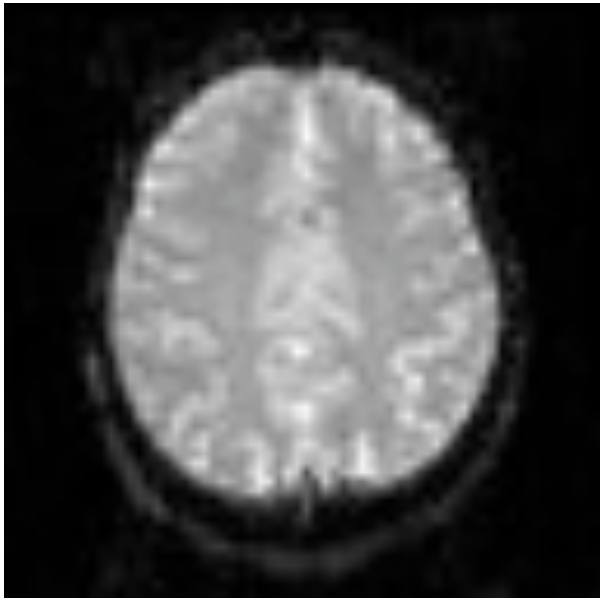
Robot control by fMRI decoding

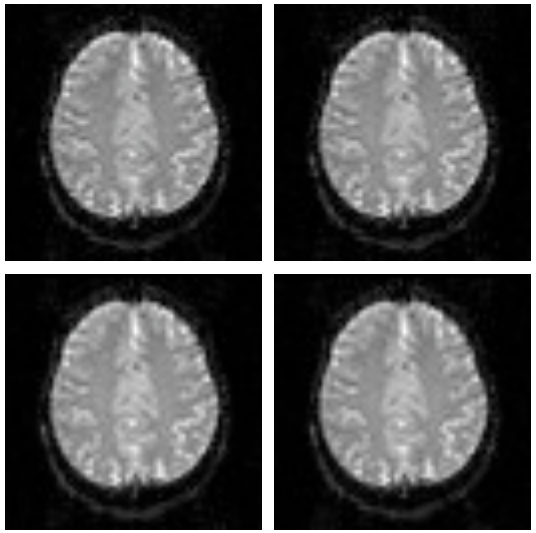


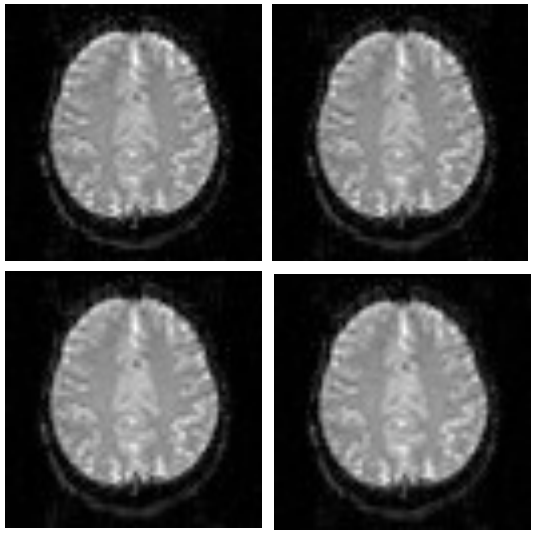
(Kimura, Imamizu, Shimada, Oztop, Harner, Kamitani, 2006;
Collaboration with Honda Research Institute)

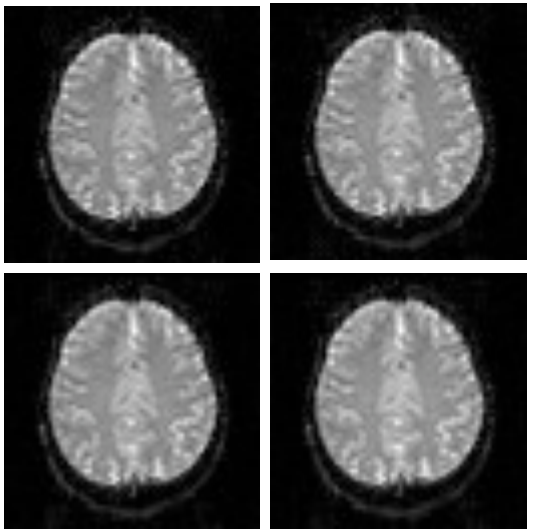
 or  or 

?

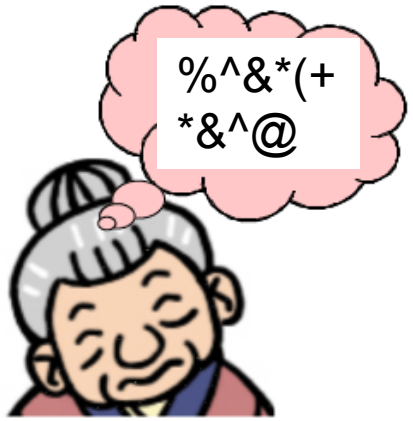








Let the machine learn!
Machine learning-based decoding



Decoding

s ← **r**

Stimulus/Behavior/Mind

Brain activity (= "*Code*")

Supervised learning:

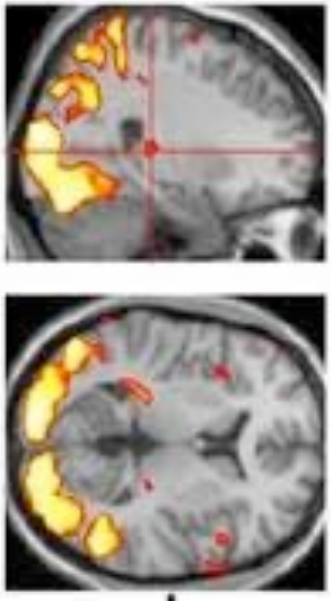
1. Collect training data: Brain activity (**r**) labeled by stimulus/task(*s*)
2. Train a decoding model using the training data: $s = f(\mathbf{r})$
3. Test the trained model with independent data

~100,000 voxels vs. 100–1,000 samples

→ linear and/or sparse models

From mapping to decoding

Functional brain mapping



Task A − Task B

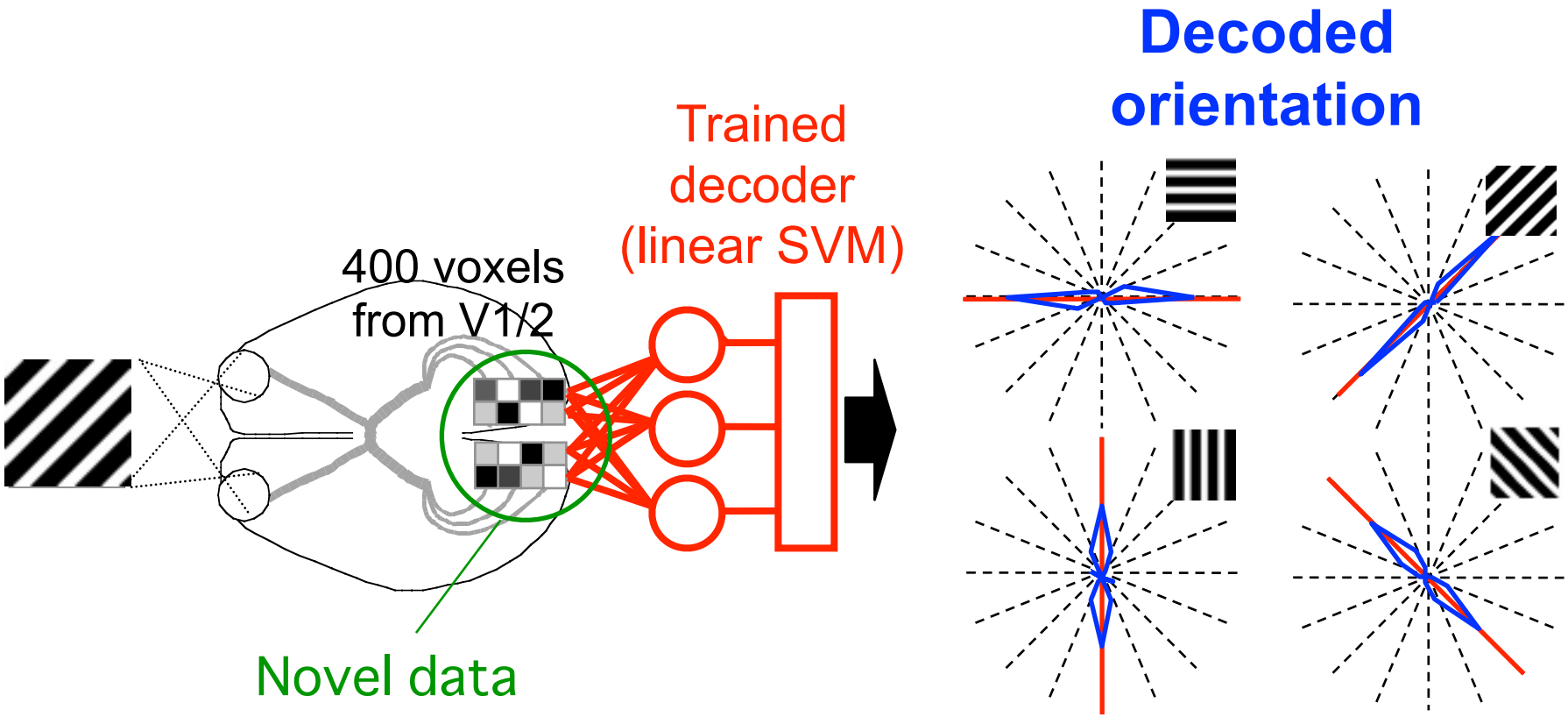
- Voxel-by-voxel analysis
- Statistical parameter estimation with whole data
- Evaluation by p-value

Brain decoding

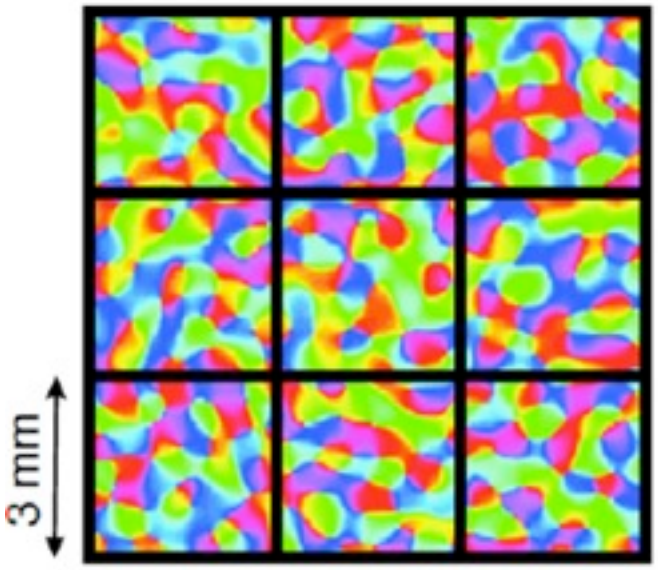
- Multi-voxel pattern
- Trial-by-trial prediction
- Evaluation by prediction accuracy/error

Decoding of visual orientation

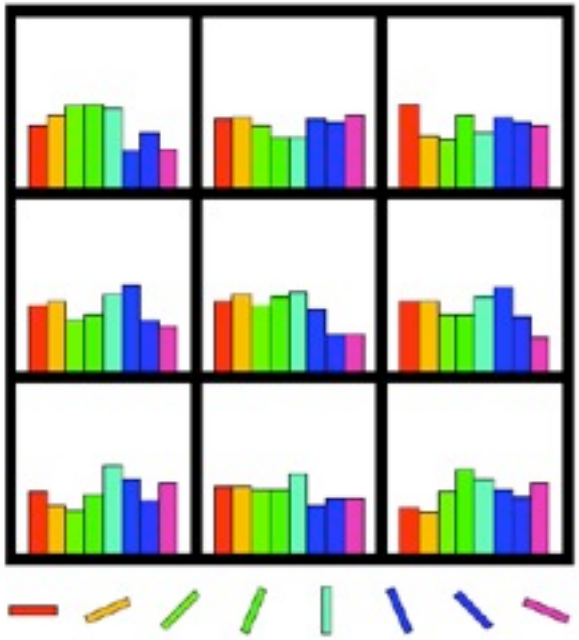
(Kamitani and Tong, *Nat Neurosci* 2005; *Curr Biol* 2006; Kamitani and Sawahata, *Neuroimage* 2008; Tong et al. *Neuroimage* 2012)



“Hyperacuity” in fMRI decoding



(cf., Boynton, 2005; Rojer and Schwartz, 1990)

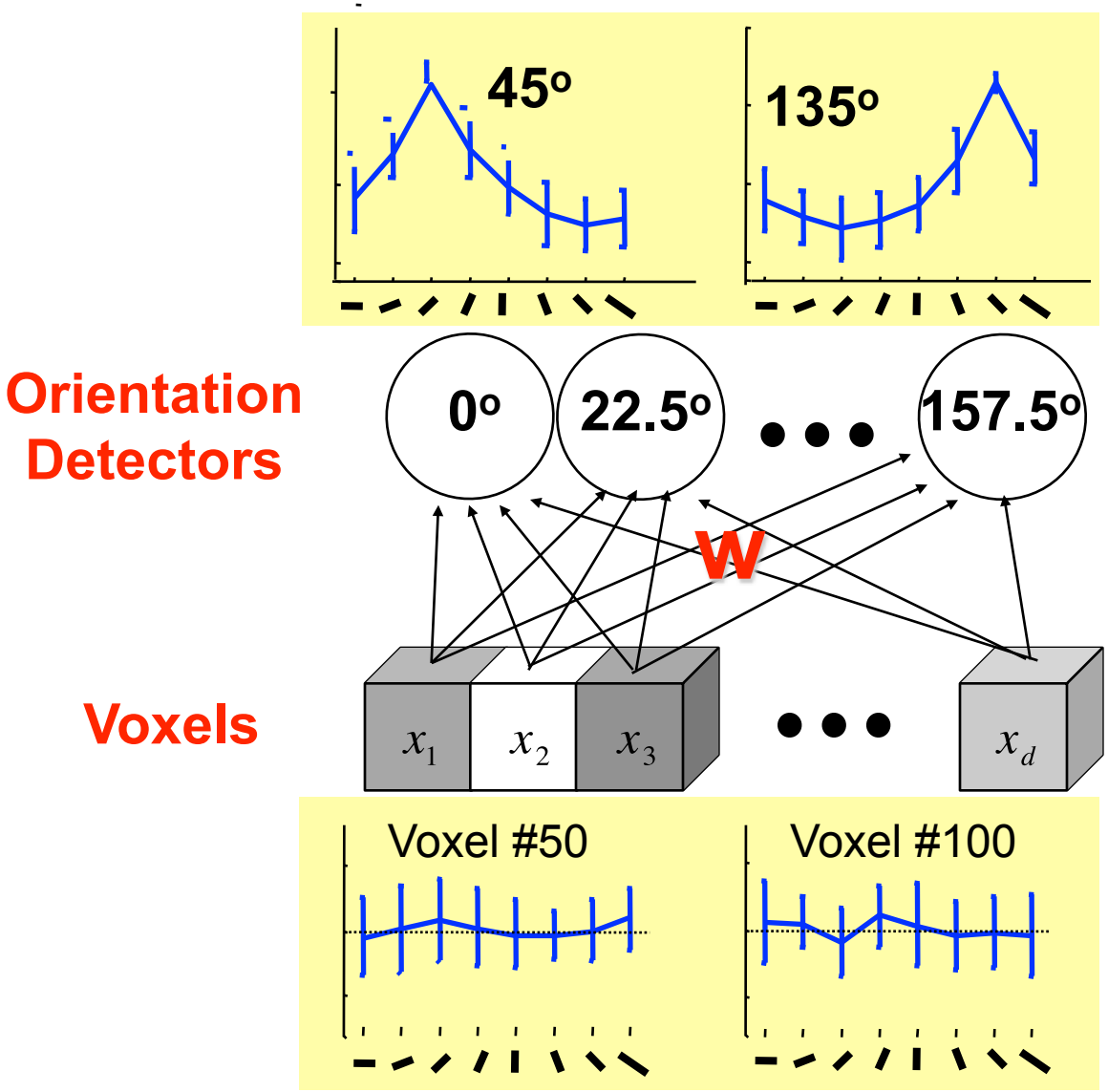


Information from subvoxel representation via random bias of voxel sampling due to irregular columnar and/or vasculature structure (Kamitani and Tong, 2005)

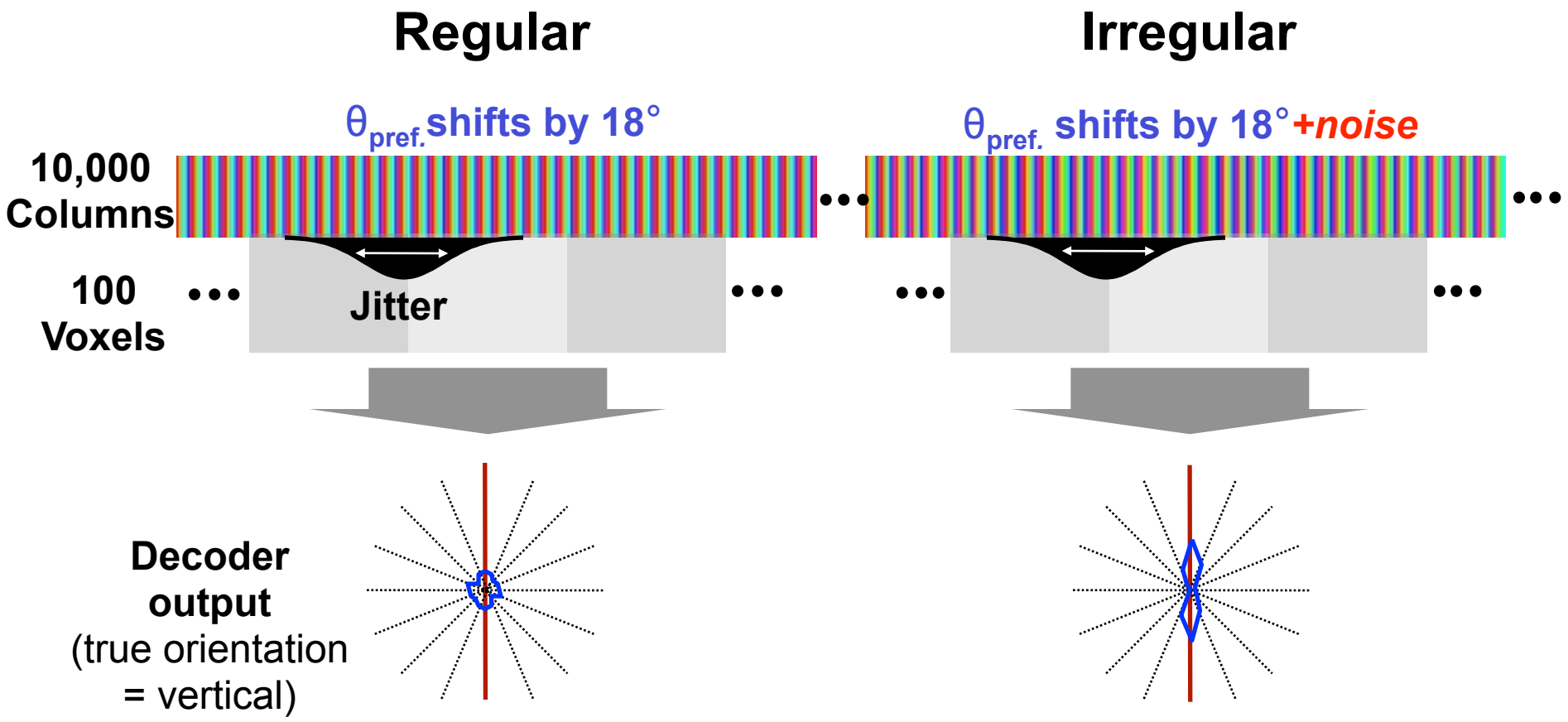
(See also: Op de Beeck, 2009; Kamitani & Sawahata, 2009; Gardner, 2009; Shmuel et al. 2009; Kriegeskorte et al 2009; Mannion et al., 2009; Swisher et al. 2010; Freeman et al. 2011; Clifford et al., 2011; Chaimow et al 2011)

Ensemble feature selectivity

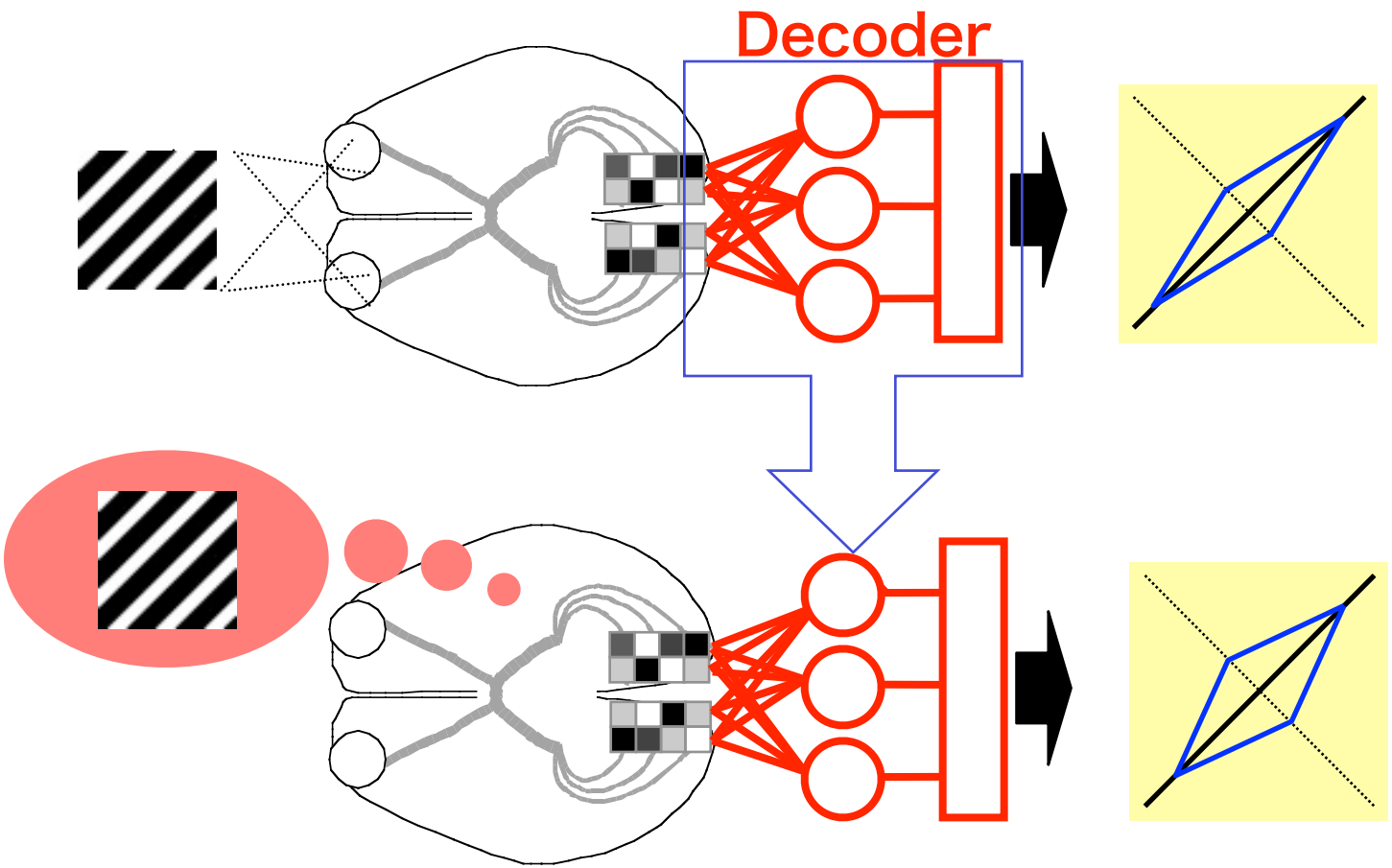
(Kamitani & Tong, 2005, 2006)



Voxel sampling of columns: 1D Simulation



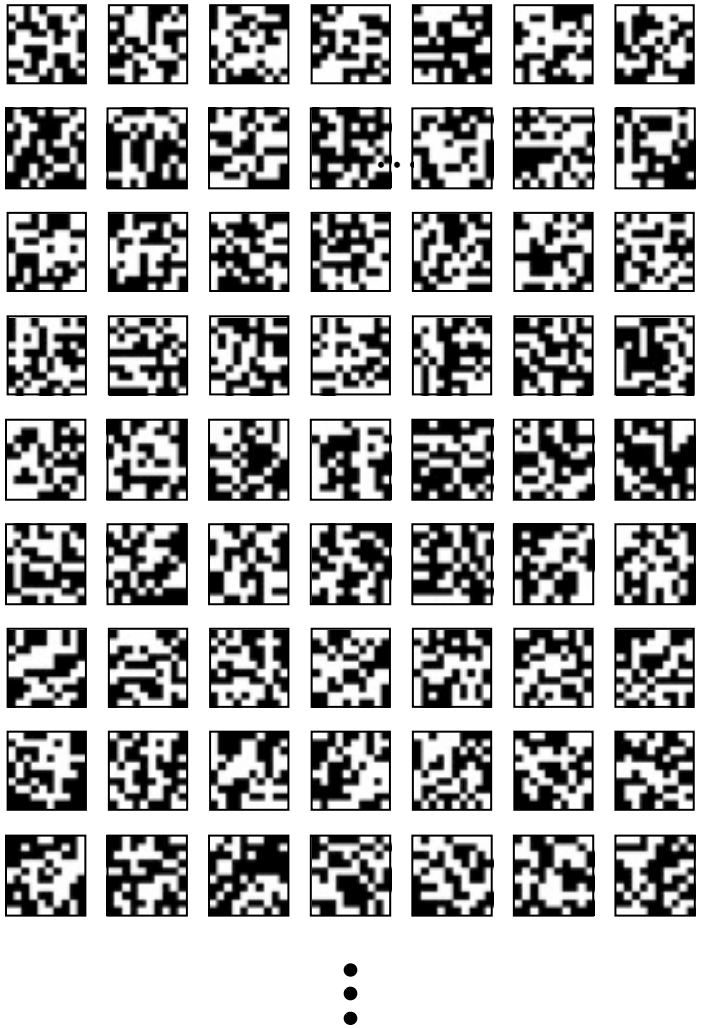
Decoding subjective state



Common neural representation
for perception and imagery

(Kamitani and Tong, 2005, 2006; Stokes et al.,2009; Harrison et al., 2009)

Classification of all possible visual images



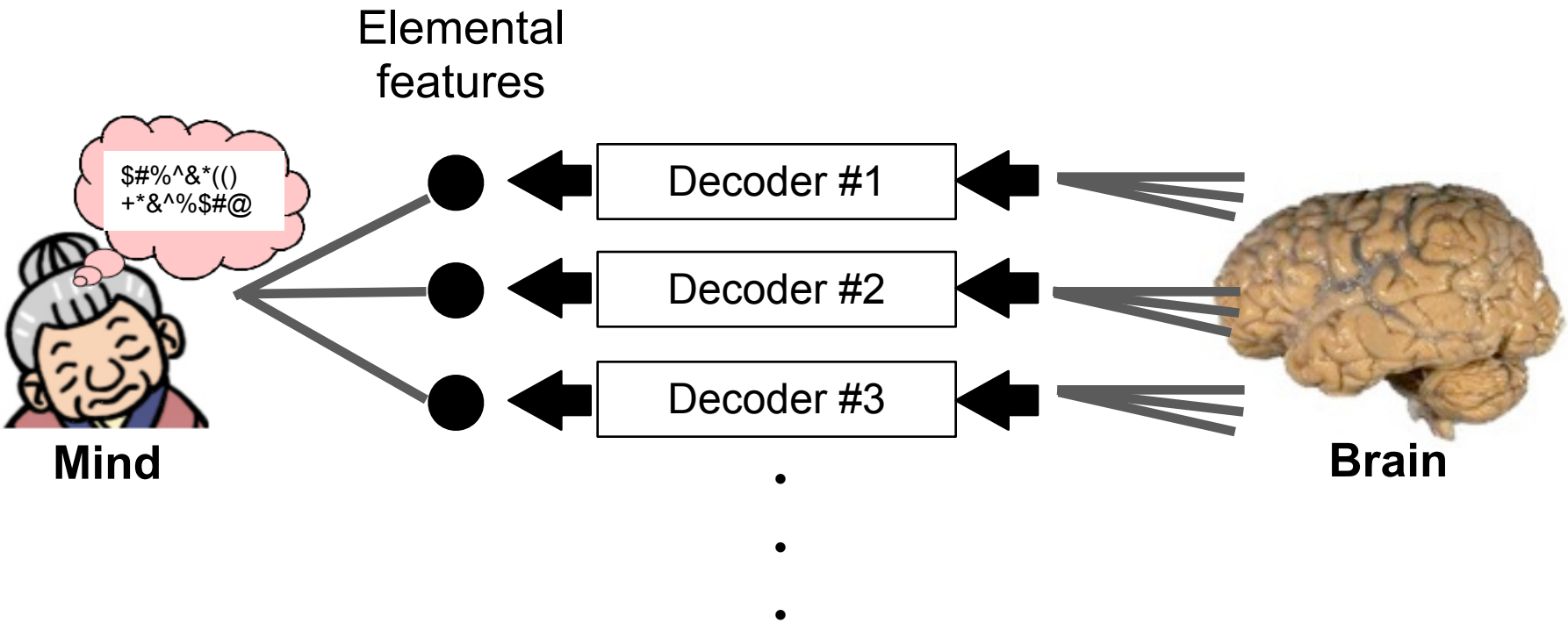
10 x 10 binary pixels

2^{100} =

10000000 · · · possible images

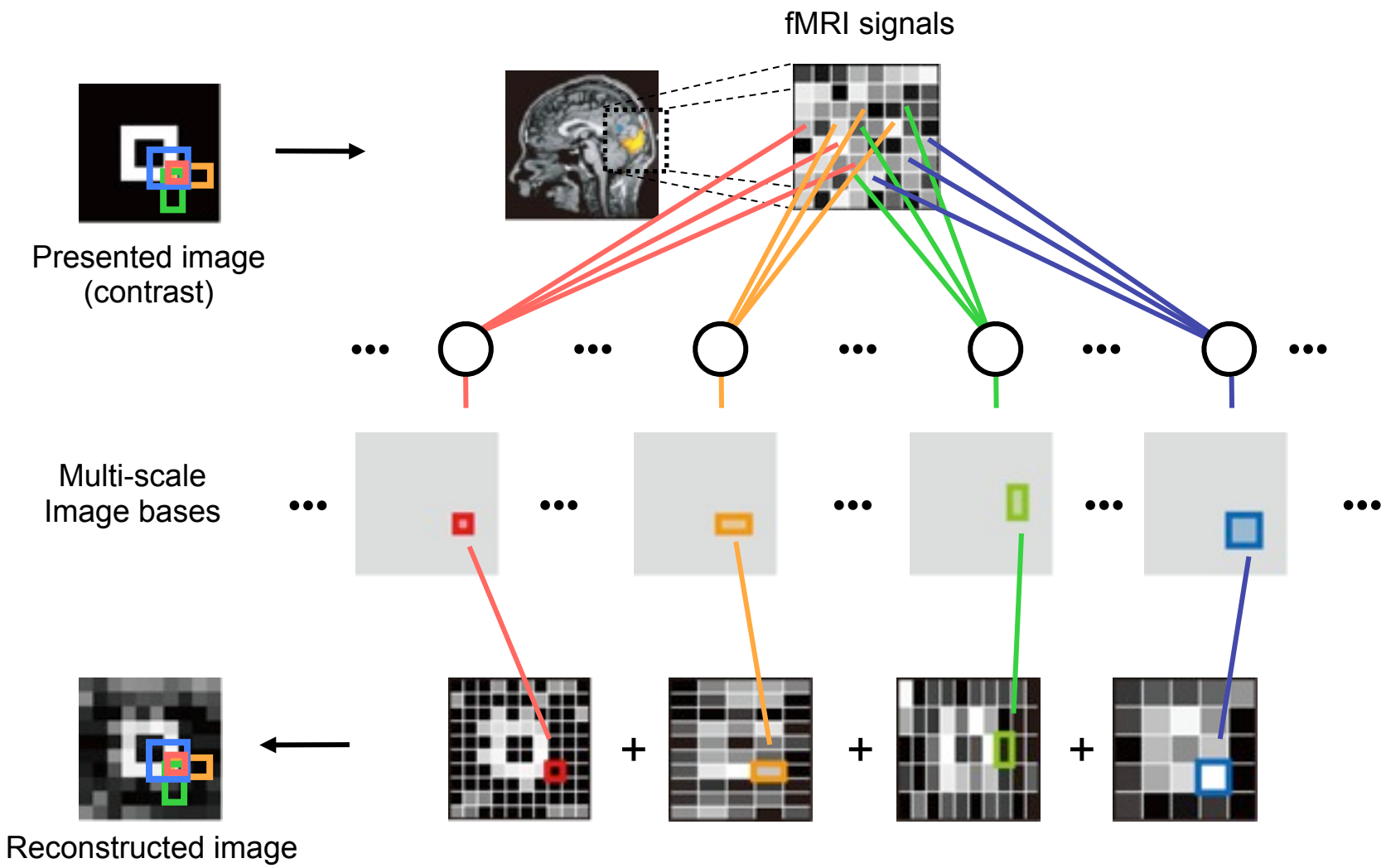
~30 zeros

Modular decoding



(Miyawaki, Uchida, Yamashita, Sato, Morito,Tanabe, Sadato, Kamitani, *Neuron* 2008; Fujiwara, Miyawaki, Kamitani, *NIPS* 2009, *Neural Computation* 2013)

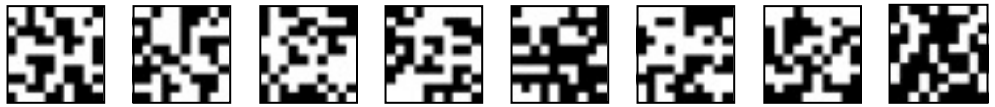
Reconstruction model



Experimental procedure

Training

~400 random images (~ 1 hour)

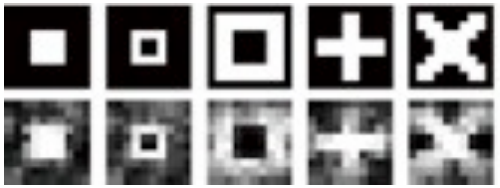


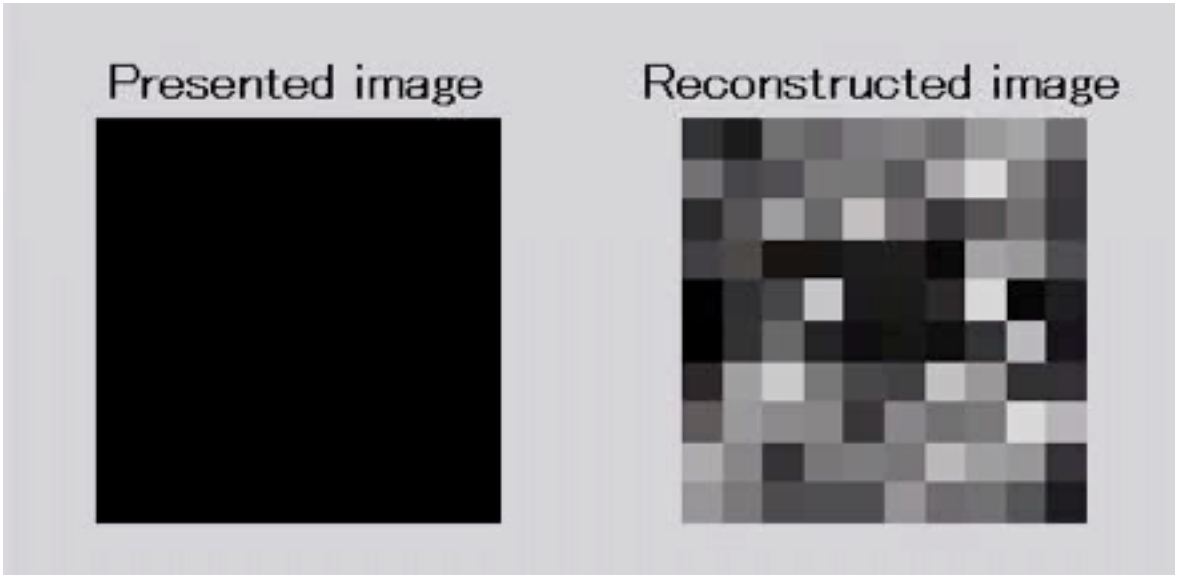
Test

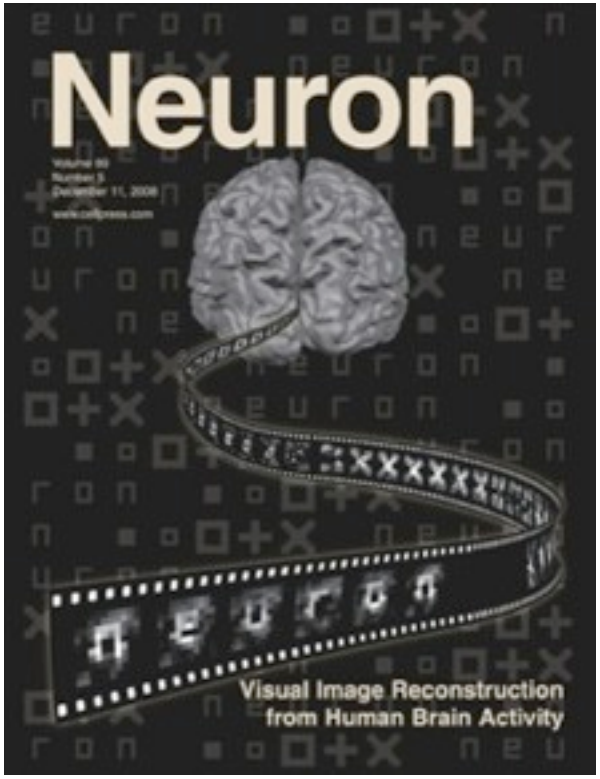
Geometric shapes, alphabets, random images (not used in training)

All voxels in V1 and V2 served as input, and sparse estimation (ARD) automatically selected relevant voxels (Yamashita, Sato, Yoshioka, Tong, Kamitani, *Neuroimage* 2008).

Reconstruction results

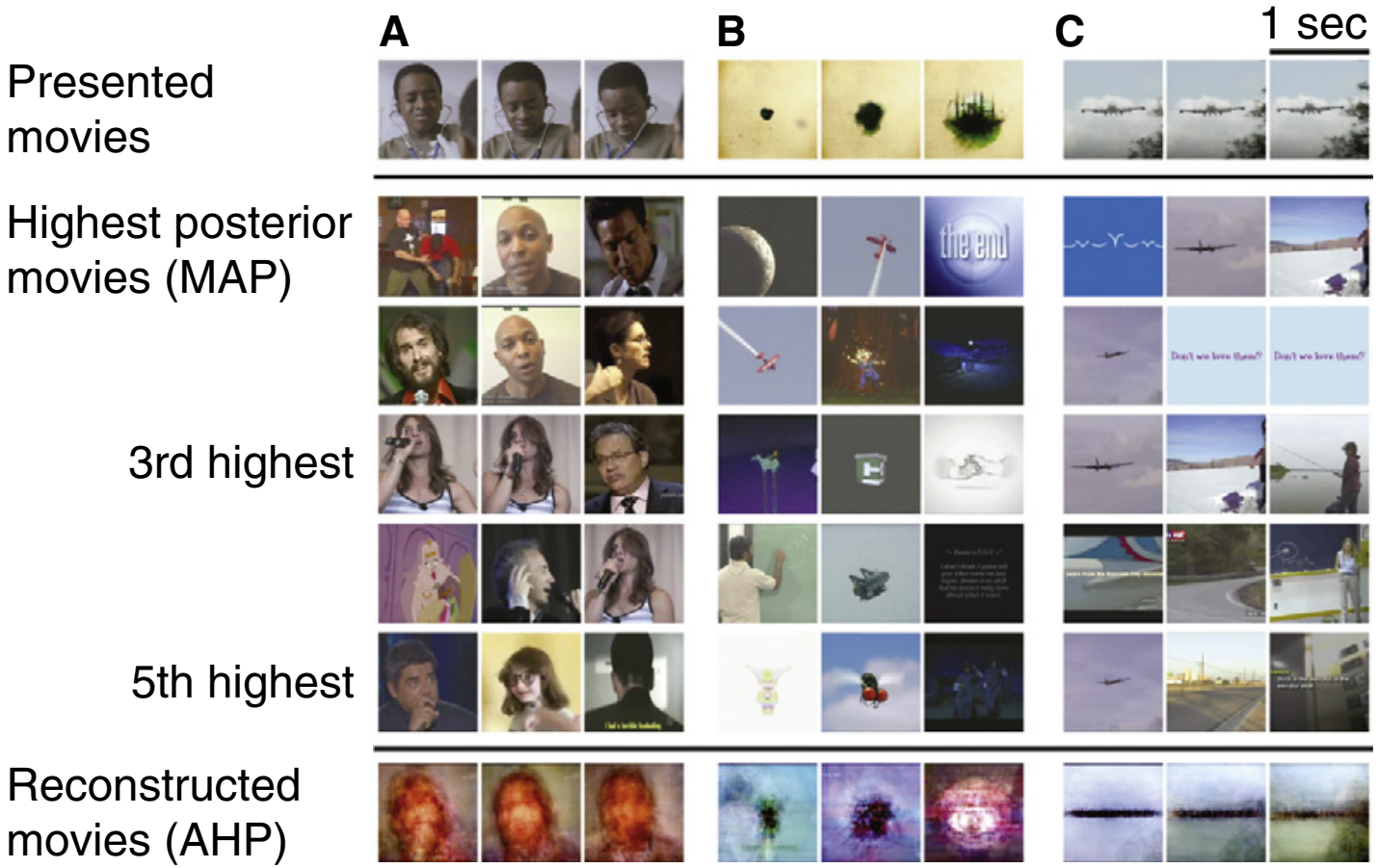






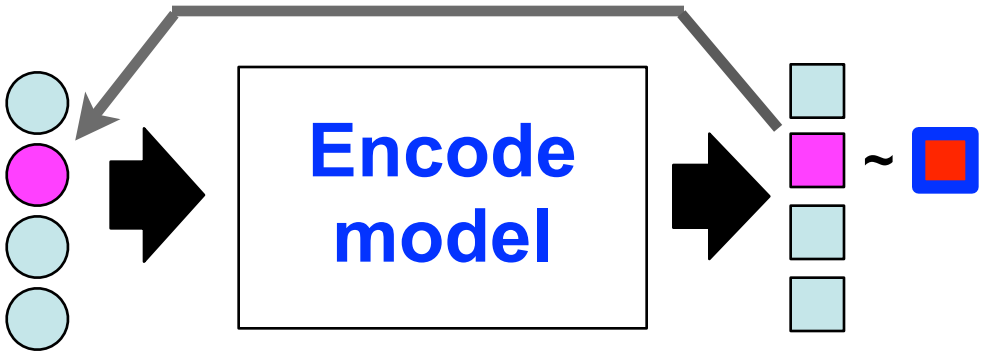
(Miyawaki, Uchida, Yamashita, Sato, Morito,Tanabe, Sadato, Kamitani, *Neuron* 2008)

Matching with Youtube video database

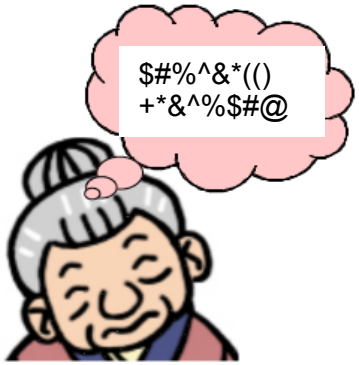


(Nishimoto, Gallant et al., Curr Biol 2011)

Encode and decode models

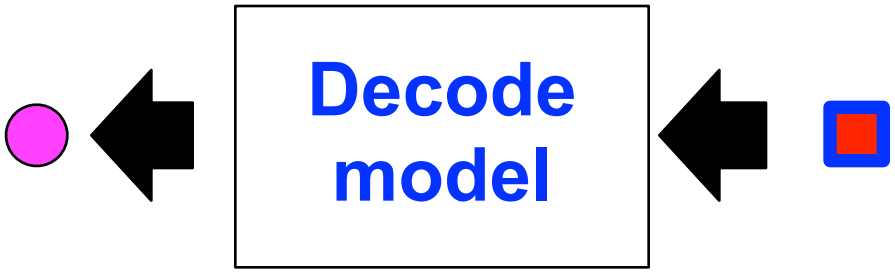


(Kay et al. Nature 2008;
Mitchell et al. Science 2008;
Nishimoto et al., Curr Biol 2011)



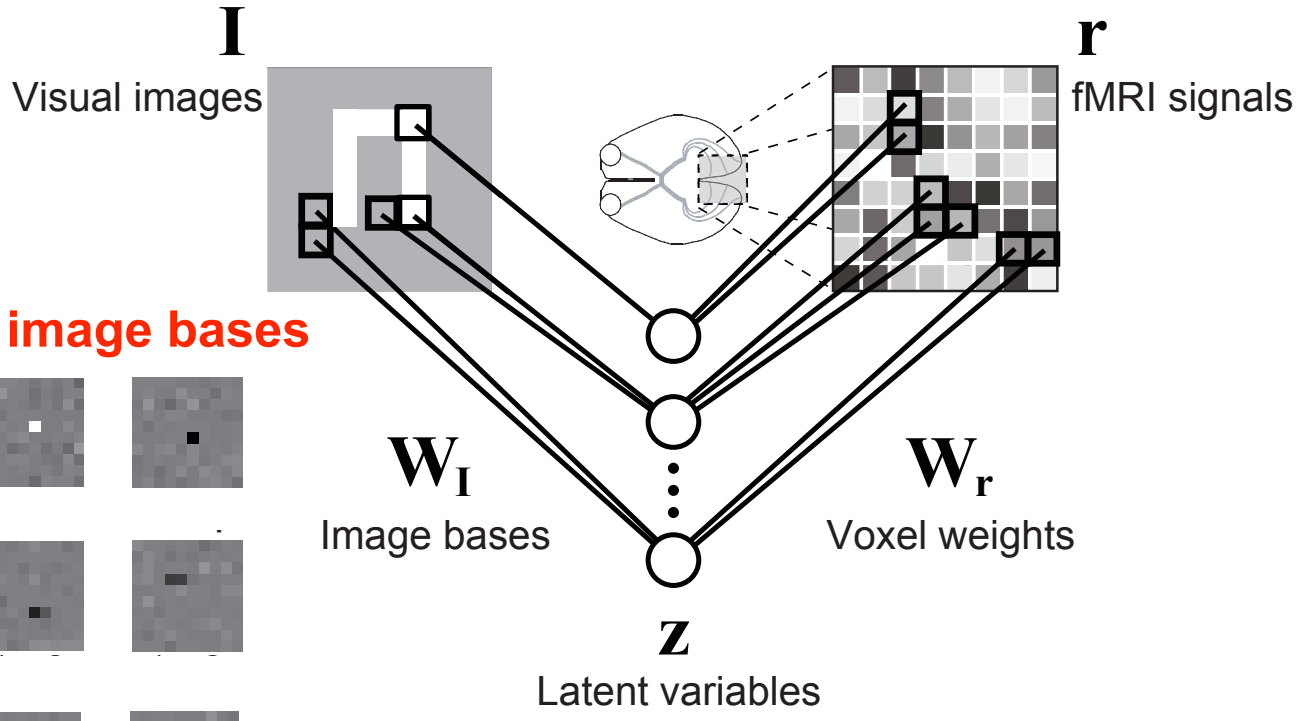
Mind

Brain

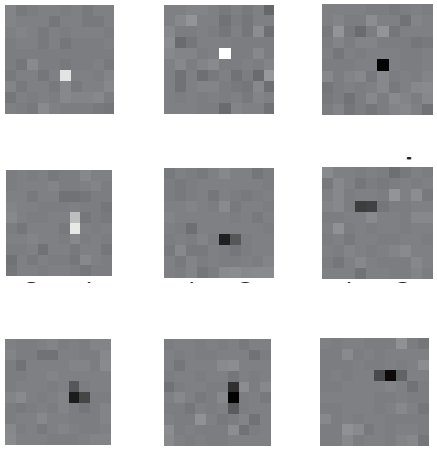


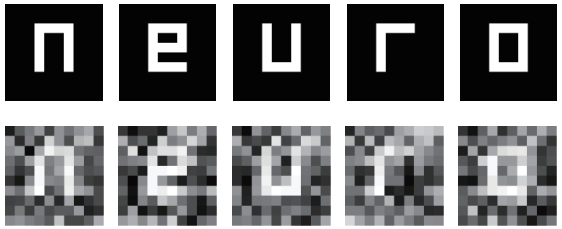
(Miyawaki et al. Neuron 2008)

Encode and decode models derived from Bayesian CCA



Estimated image bases



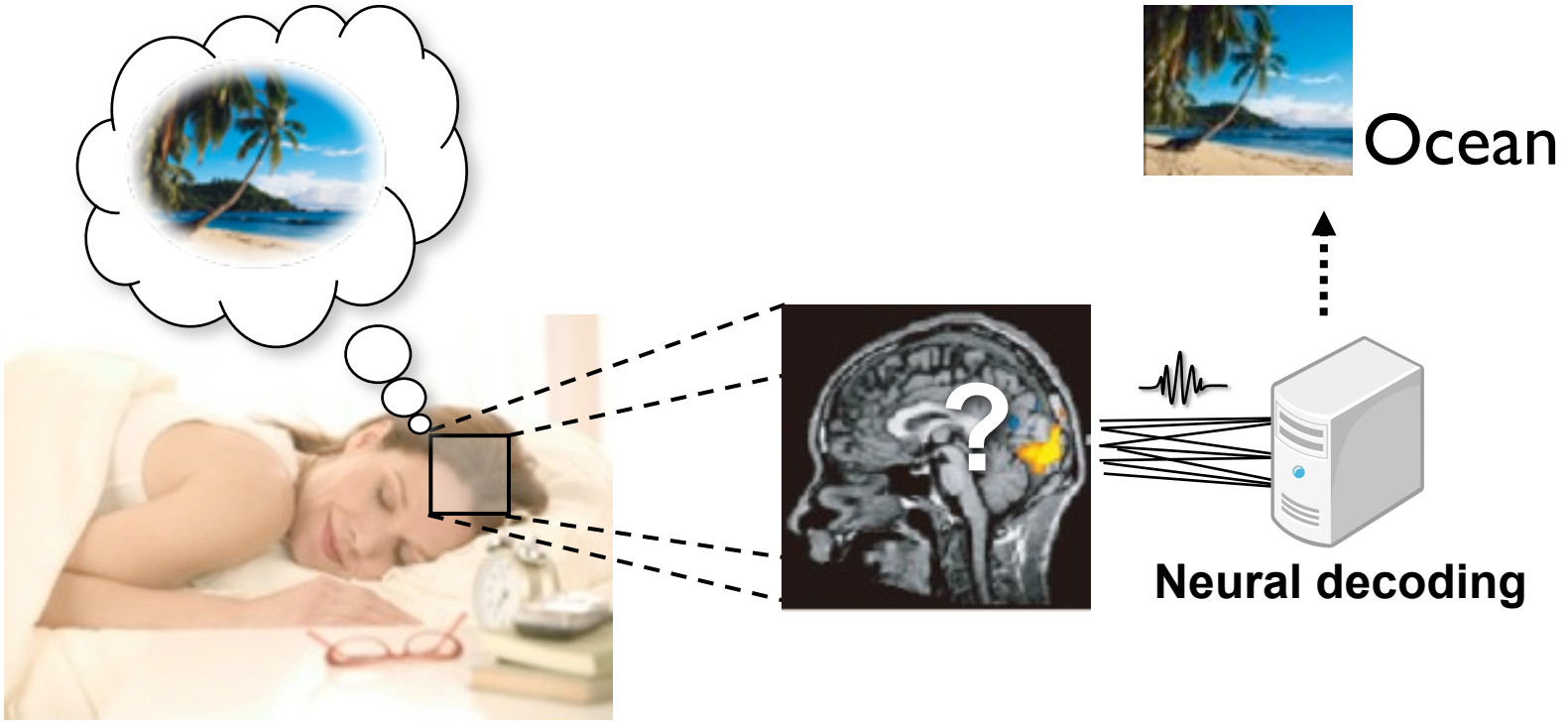


Encode model $P(\mathbf{r}|\mathbf{I})$
Decode model $P(\mathbf{I}|\mathbf{r})$

(Fujiwara, Miyawaki, Kamitani, *NIPS* 2009, Neural Computation 2013)

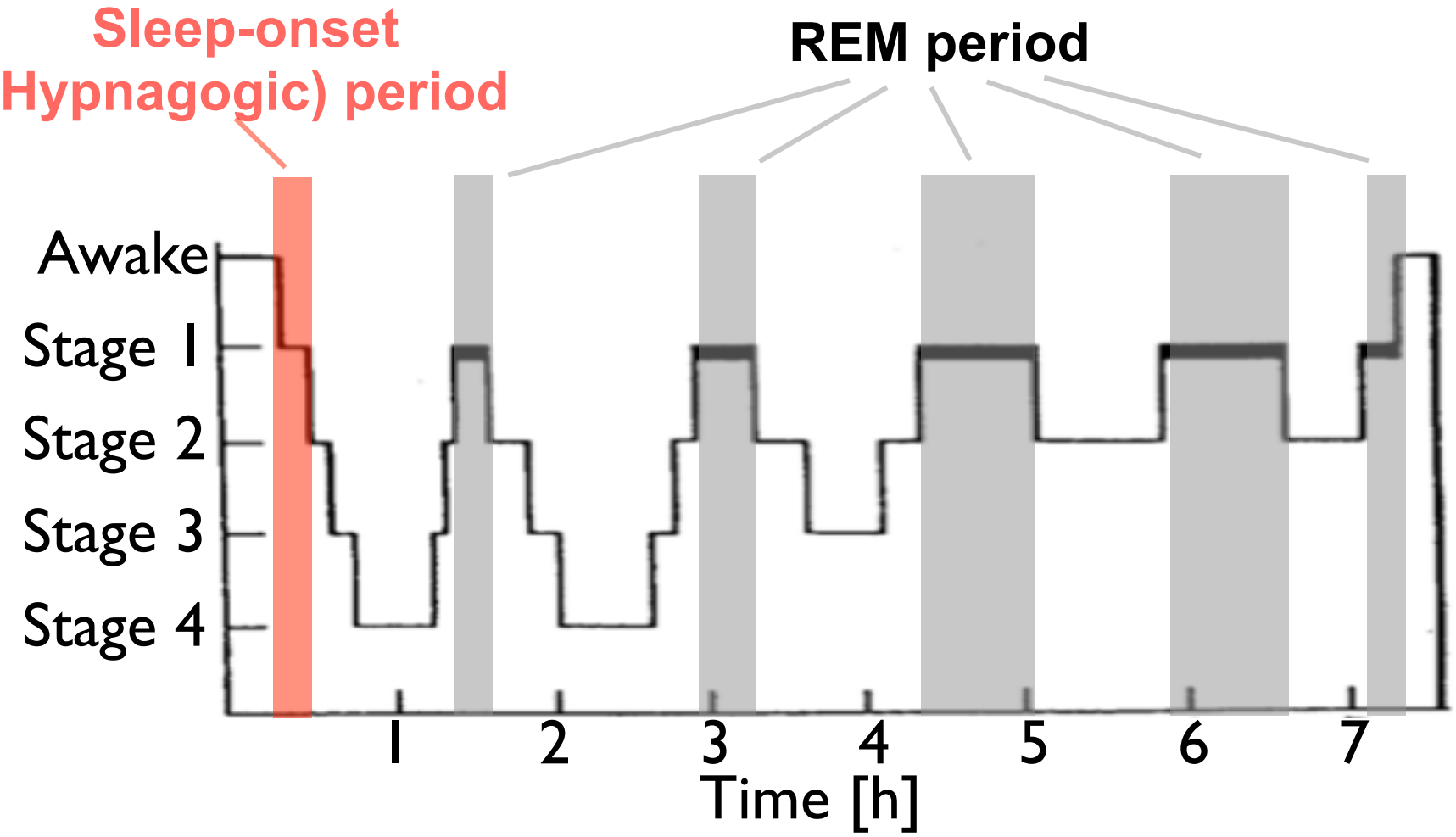

7:08
Reconstructed image
ohaasa news
将来は夢も…
脳内映像を再現

Can visual dream contents be decoded?



(Horikawa, Miyawaki, Tamaki, Kamitani, *Science* 2013)

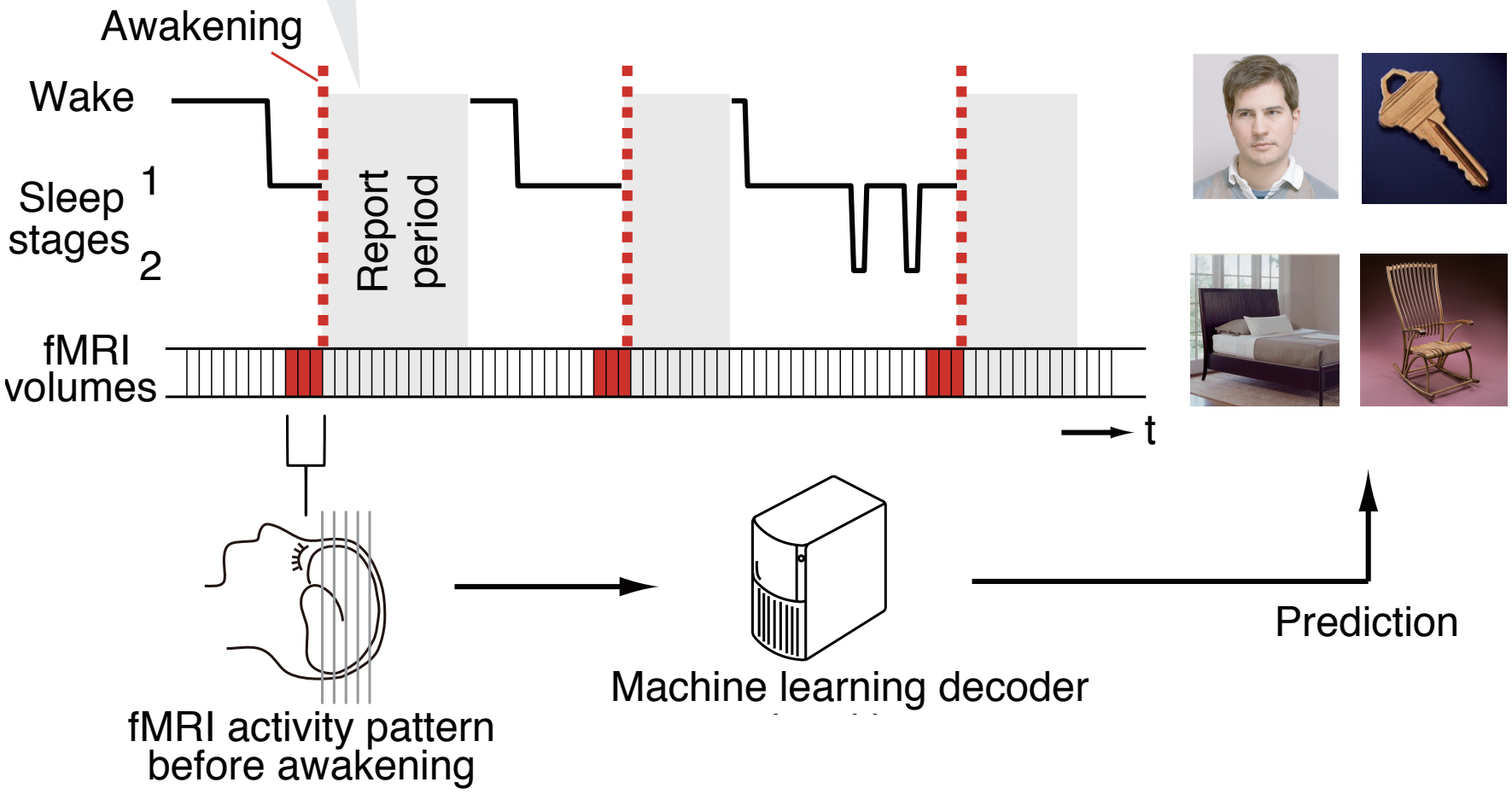
Sleep-onset (hypnagogic) dream

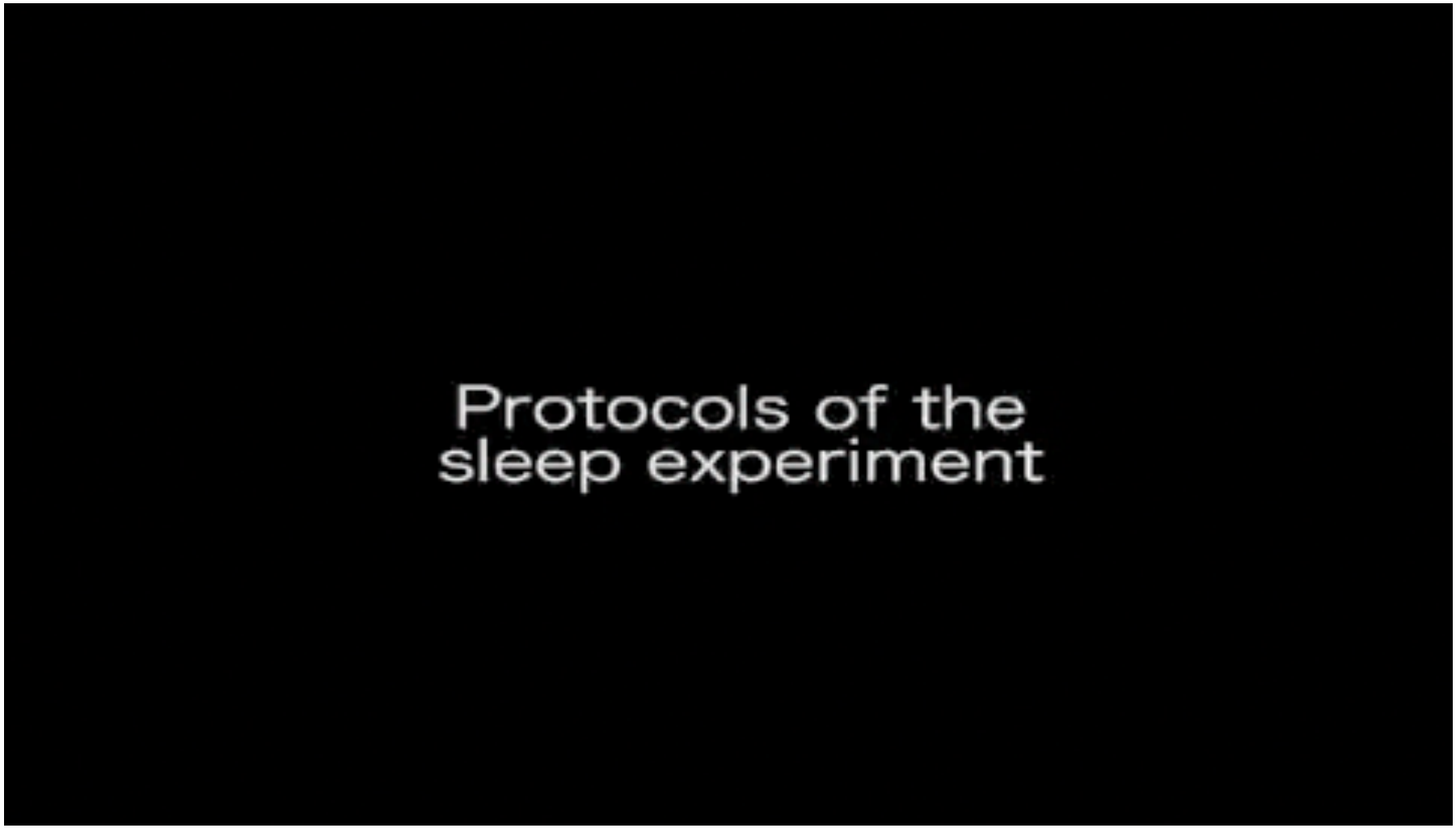


Similar dream report to REM in frequency, length, and content (Foulkes and Vogel,1965; Vogel et al. 1972; Oudiette et al., 2012)

Experimental overview

Yes, well, I saw a person. Yes. What it was... It was something like a scene that I hid a key in a place between a chair and a bed and someone took it.

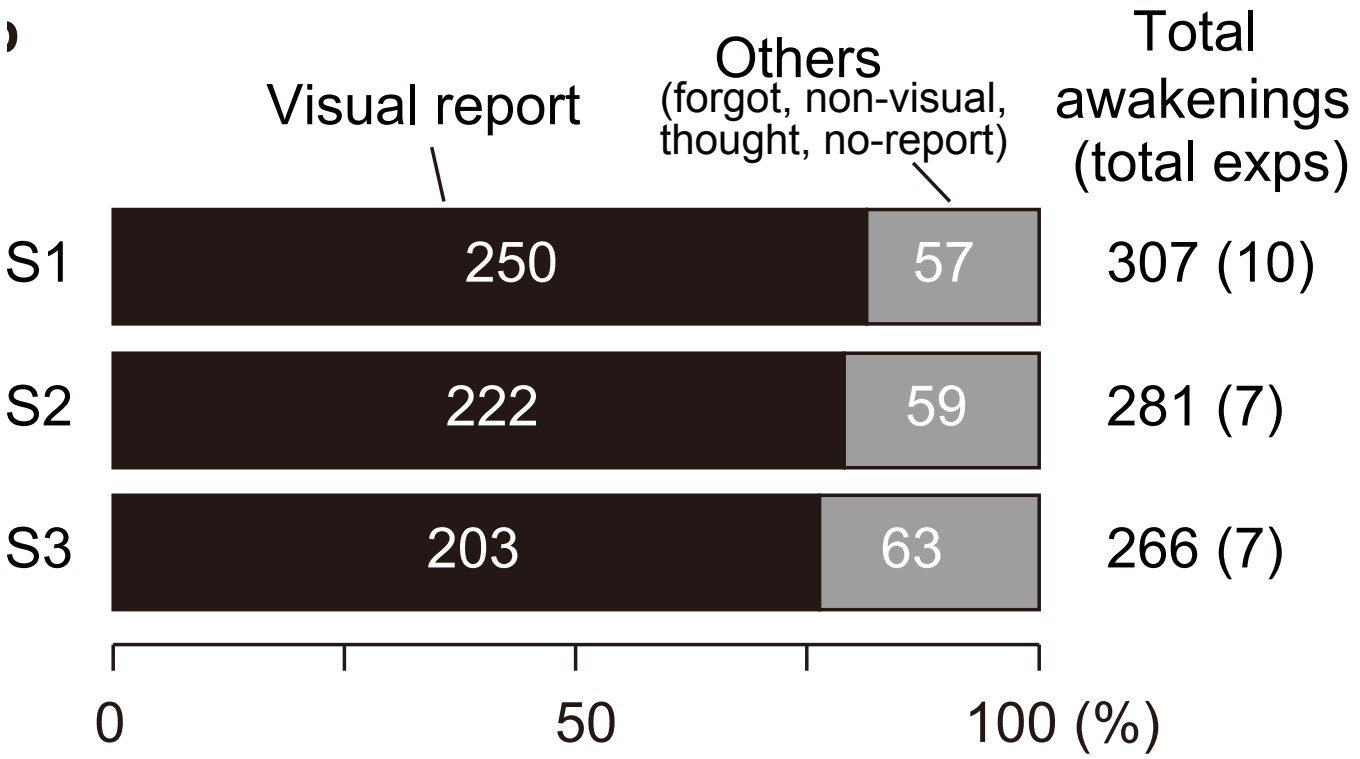



Protocols of the
sleep experiment

Verbal report example 1

Verbal report example 2

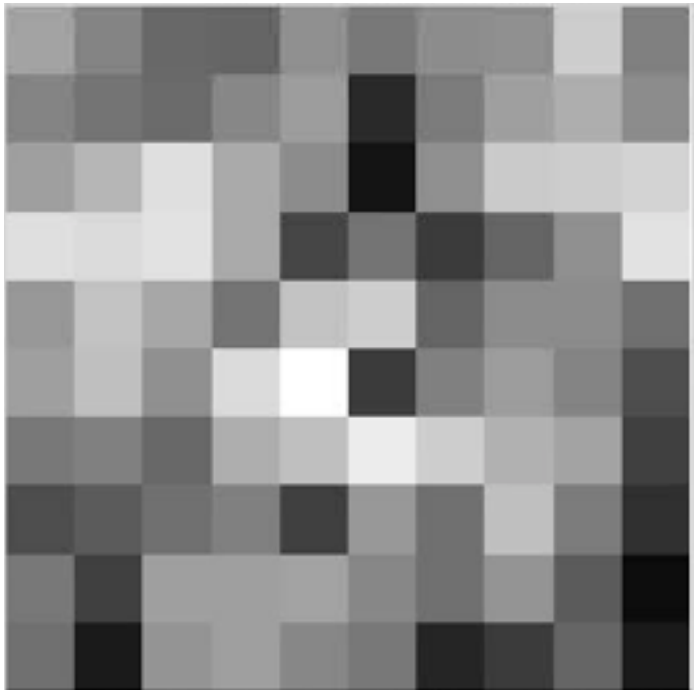
Verbal report statistics



- Repeated exps until > 200 visual reports in each subject
- Visual report in > 75% of total awakenings
- ~ 8 visual reports / hour

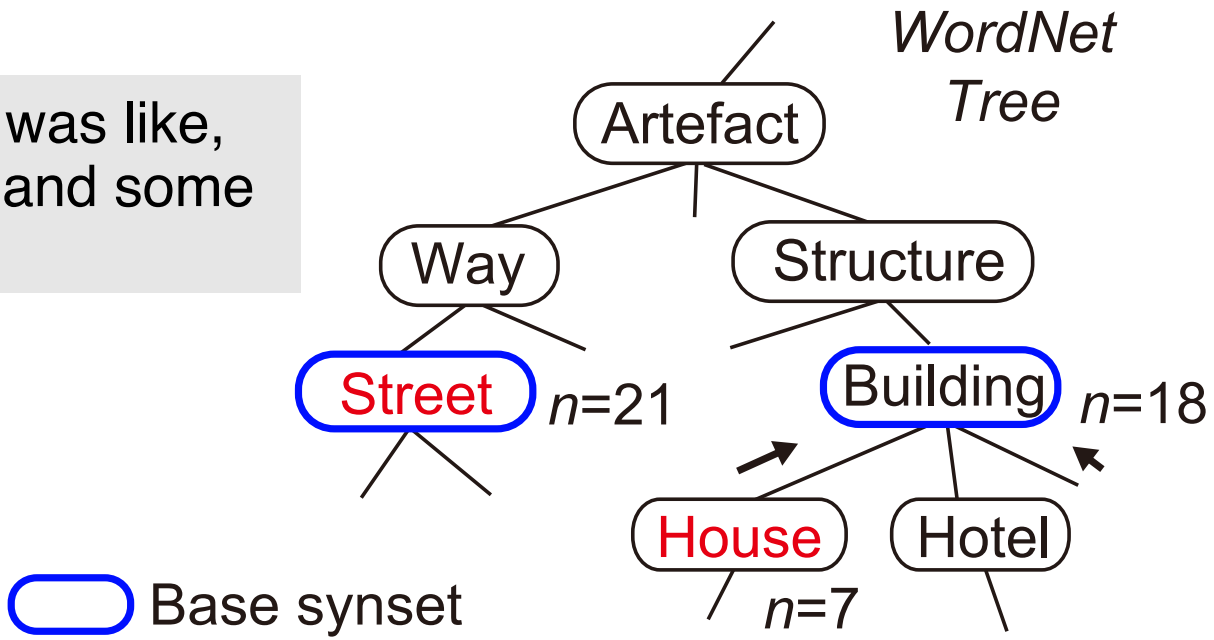
Visual image reconstruction?

“I saw Taylor was talking to me...”



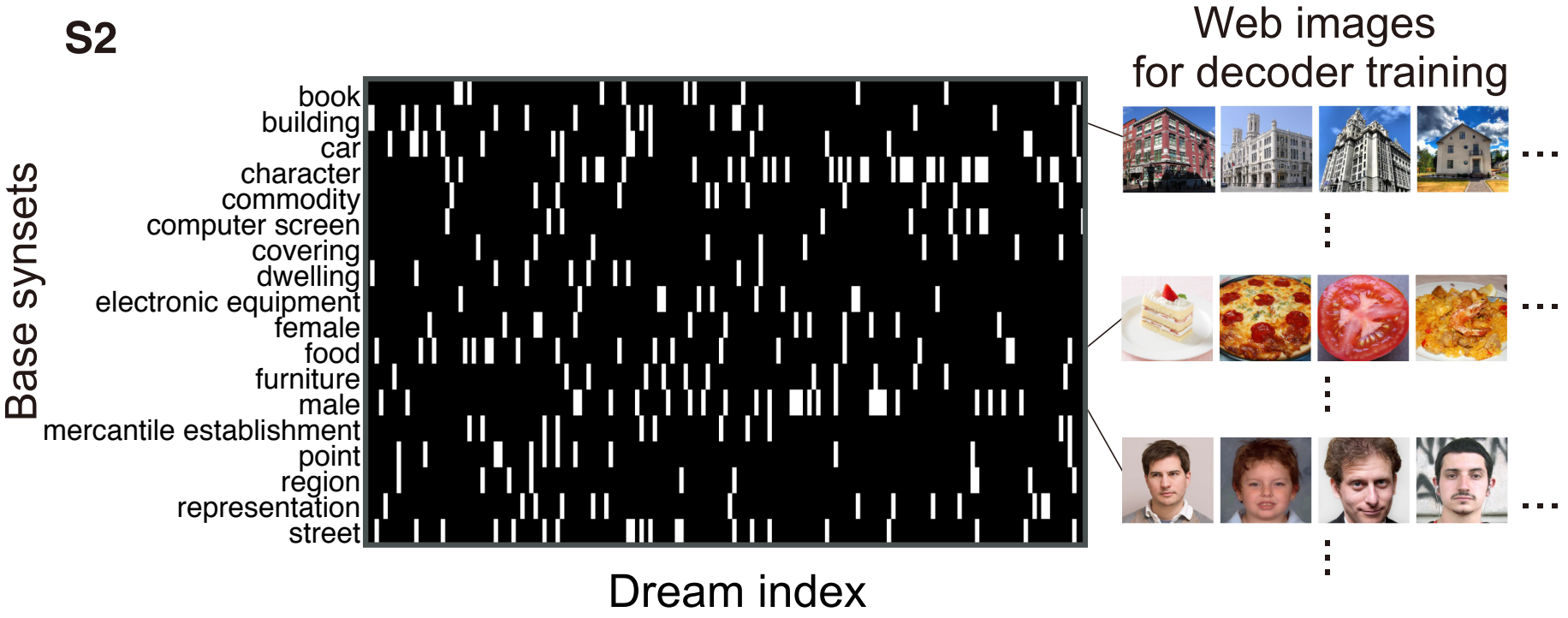
Mapping of visual words on *WordNet*

Um, what I saw now was like, a place with a street and some houses around it...

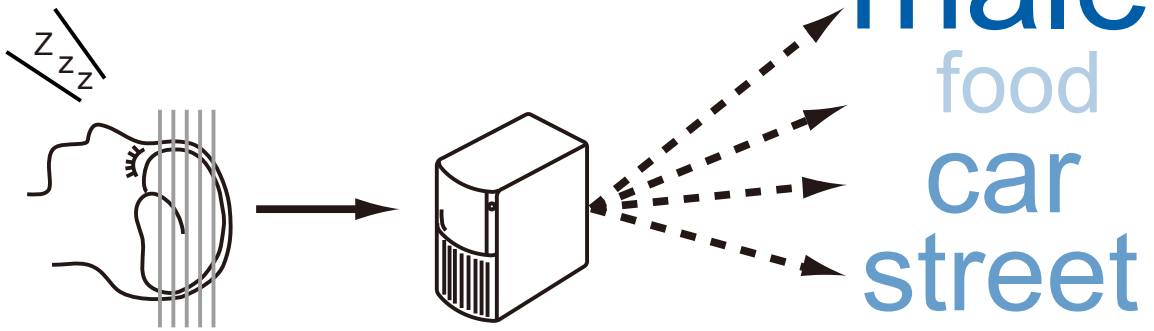


(cf., brain mapping using *WordNet*: Huth et al. 2012)

Semantic labeling and web images for decoder training



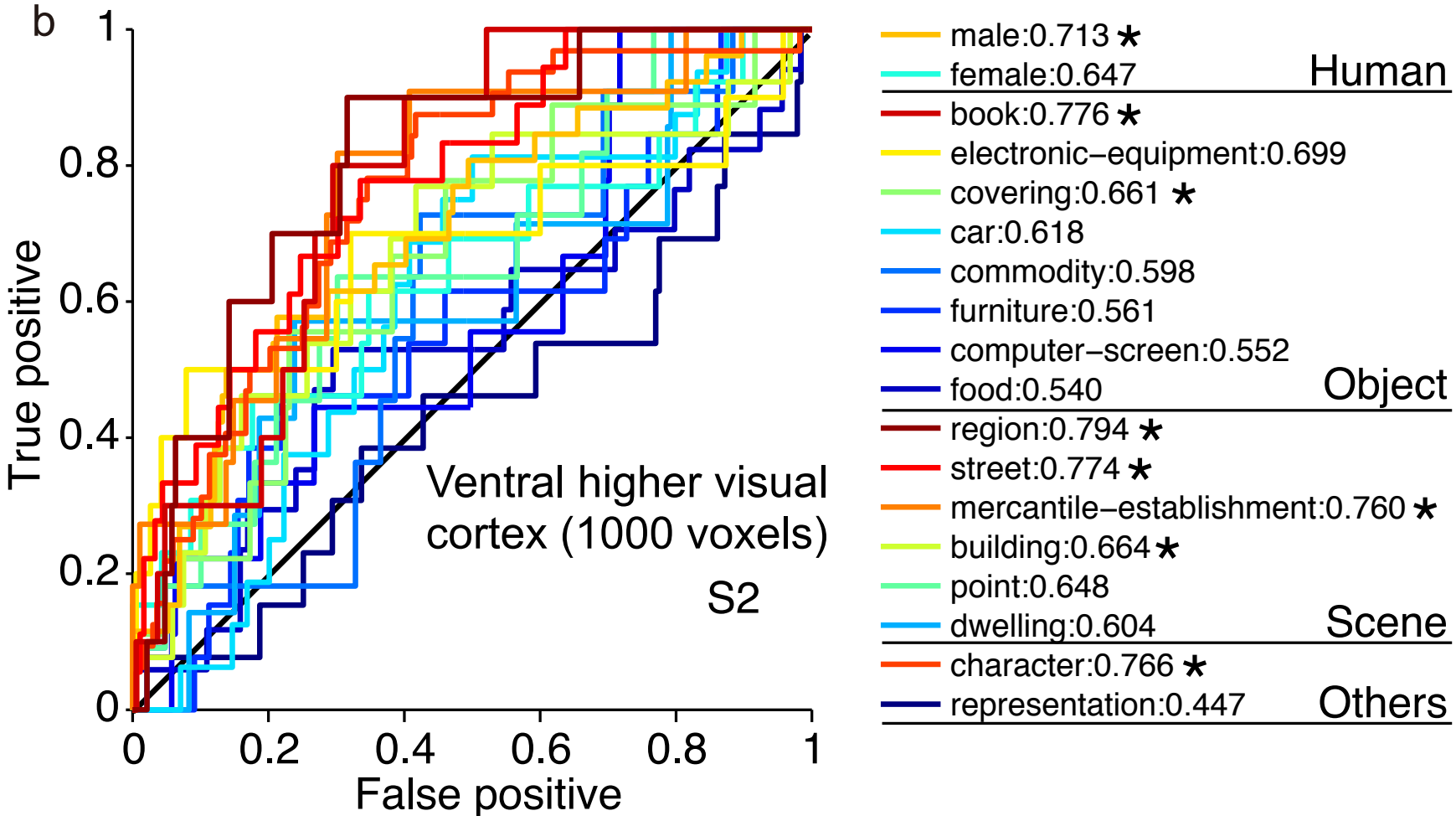
Multilabel decoding



Stimulus-trained decoder

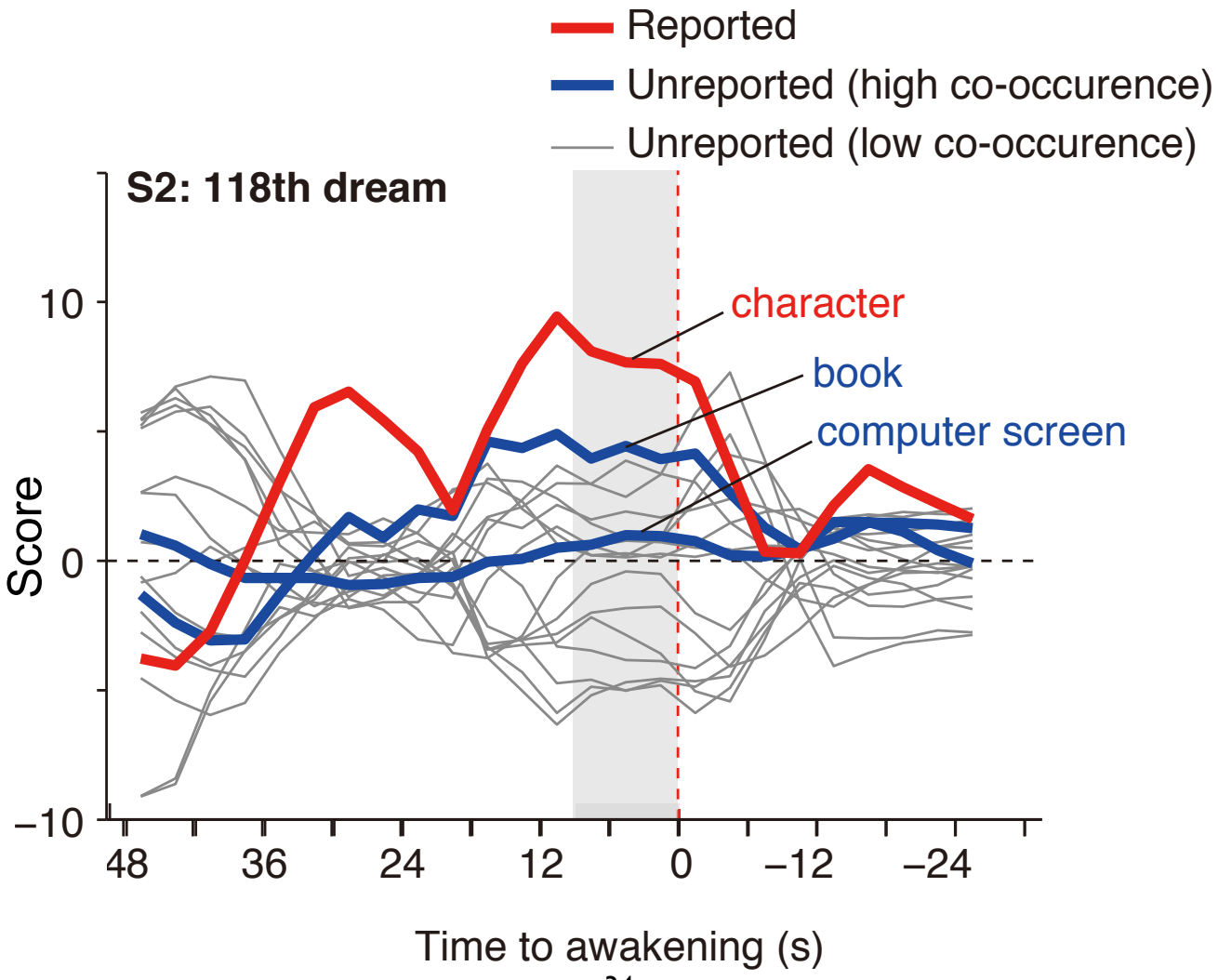
Score of each synset (linear discriminant function derived from linear SVM)

ROC analysis

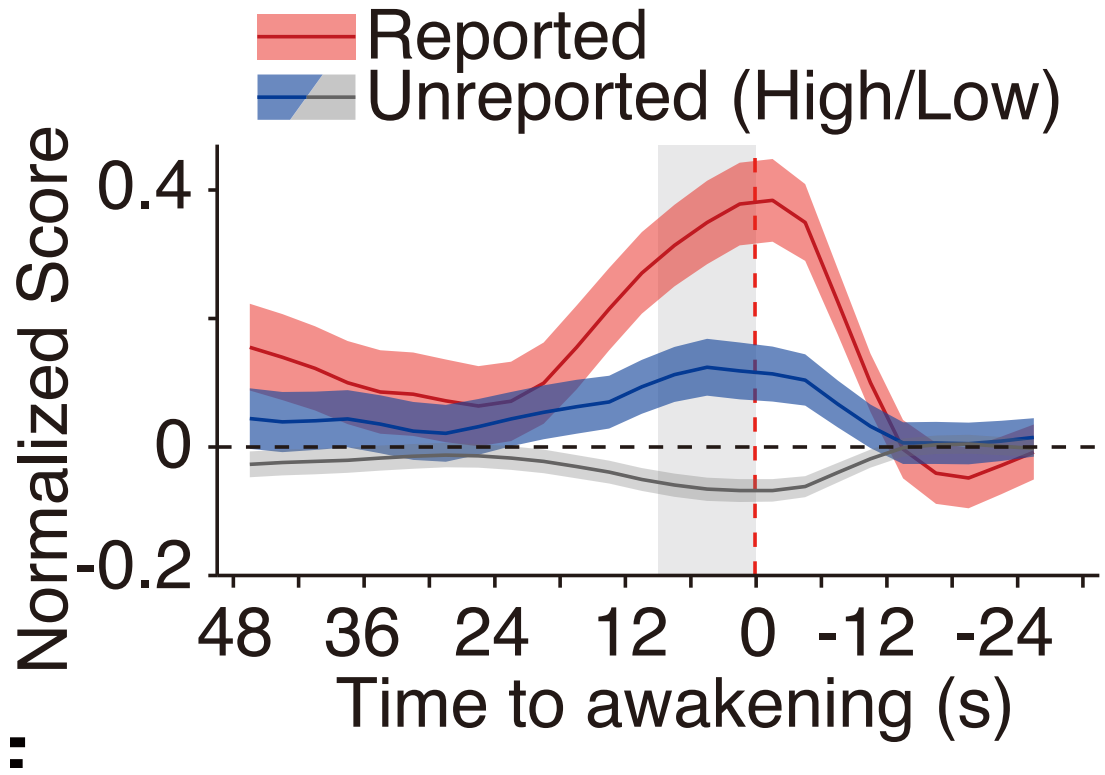


Single-trial time course

"What I was just looking at was some kind of characters. There was something like a form for composing an essay...."



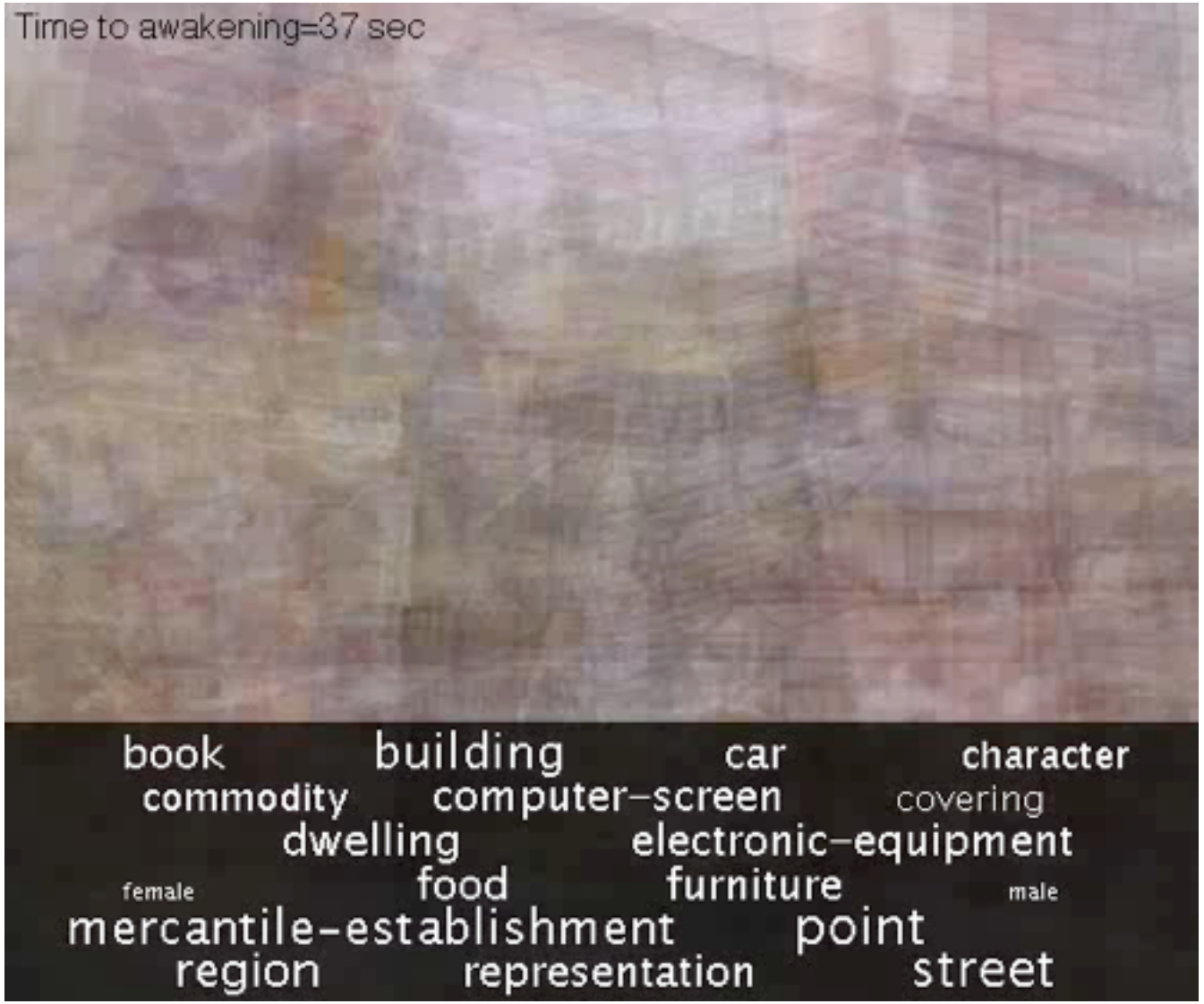
Pooled time course



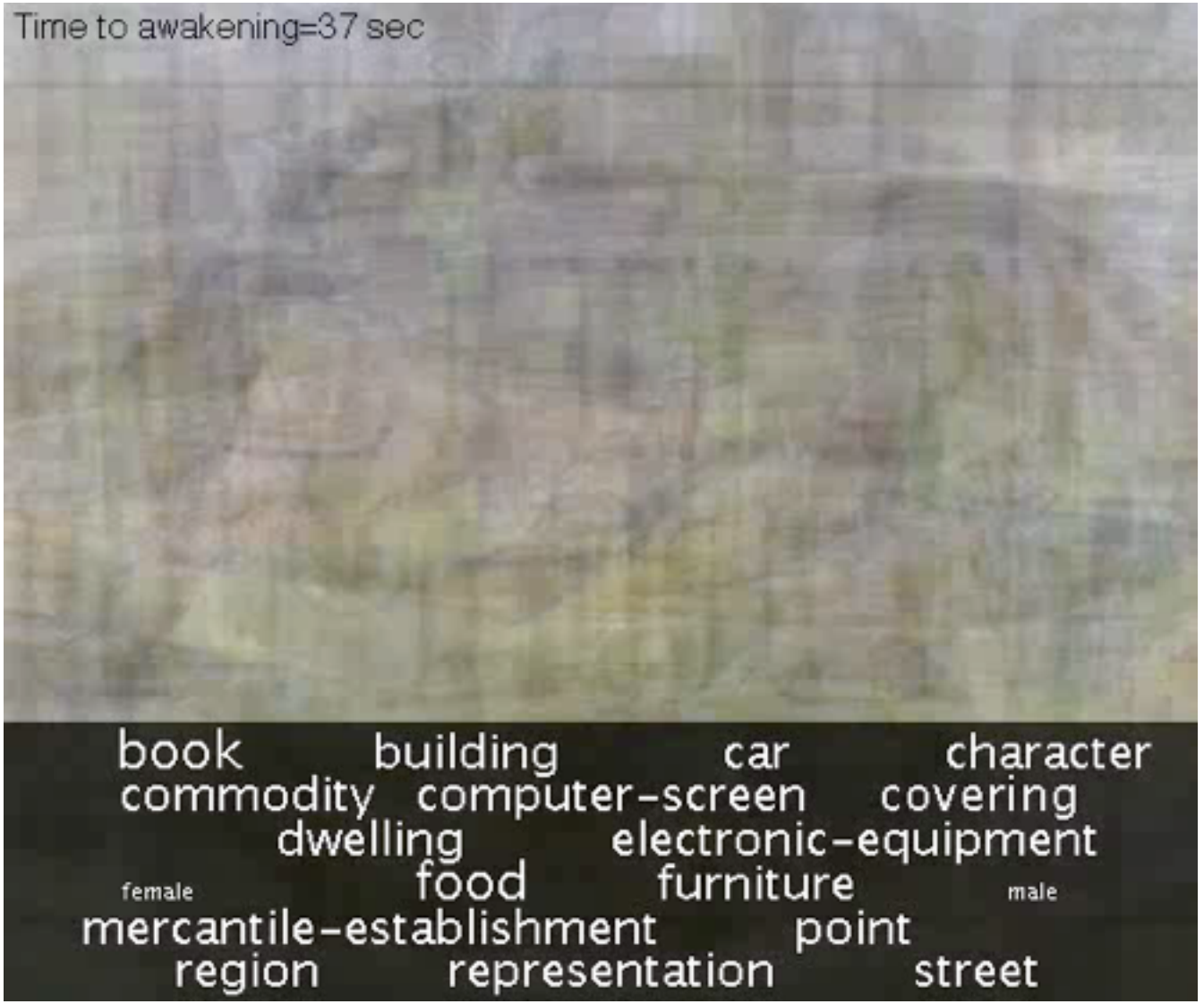
- High scores for reported synsets toward awakening

- High scores fore unreported but relevant synsets (w. high co-occurrence), potentially reflecting unreported dream contents

“What I was just looking at was some kind of characters. There was something like a form for composing an essay....”



“Yes, there were people, about 3 people, inside some sort of hall. There was a male, a female, and maybe like a child. Ah, it was like a boy, a girl, and a mother...”



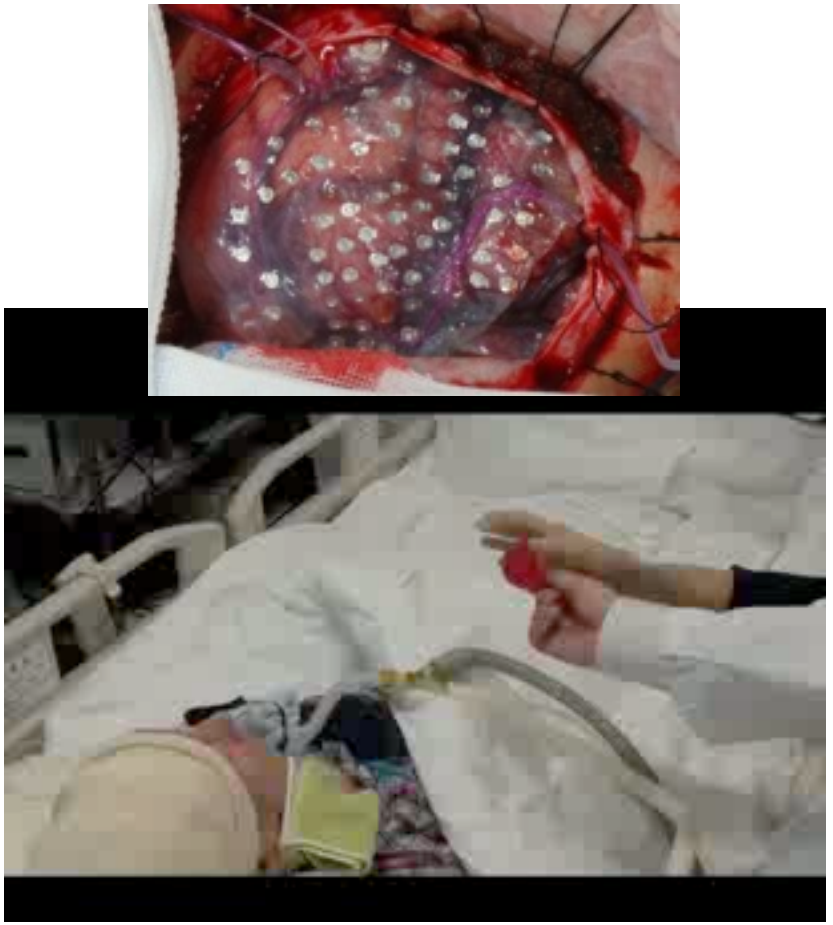
Web data as the *collective unconscious*?

Brain-web interface

Generating contents from brain signal using **web data as raw materials** with assistance of **CV, NLP, and ML**

Big brain data

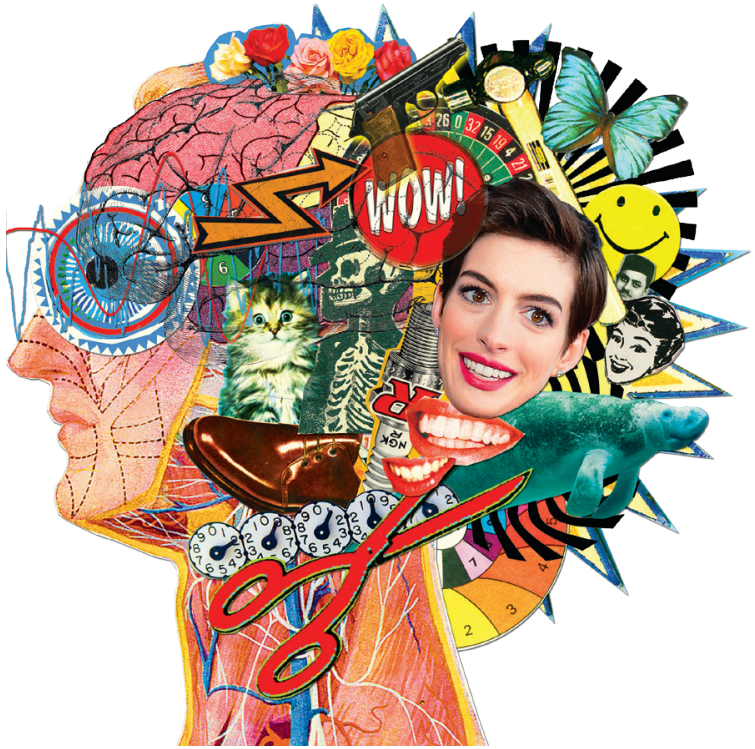
(Van Essen et al., 2013)



ECoG recording from ALS patient
96 channels, 10KHz , **6.57G/hour**
(Osaka University)

Summary

1. Machine learning-based decoding of neuroimaging data
2. Neural mind-reading
3. Modular decoding and visual image reconstruction
4. Decoding dream contents
5. Brain-web interface and big brain data



Predictive models in neuroscience

with assistance of ML, CV, NLP, and big data

2013.05.13 ガリレオ第2シーズン第五話

“Galileo” Season 2, Episode 5

Acknowledgments

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Yukuke Fujiwara

Vanderbilt
Frank Tong

NIPS
Norihito Sadato

Data and codes are available at:
http://www.cns.atr.jp/dni/
(Department of Neuroinformatics, ATR)