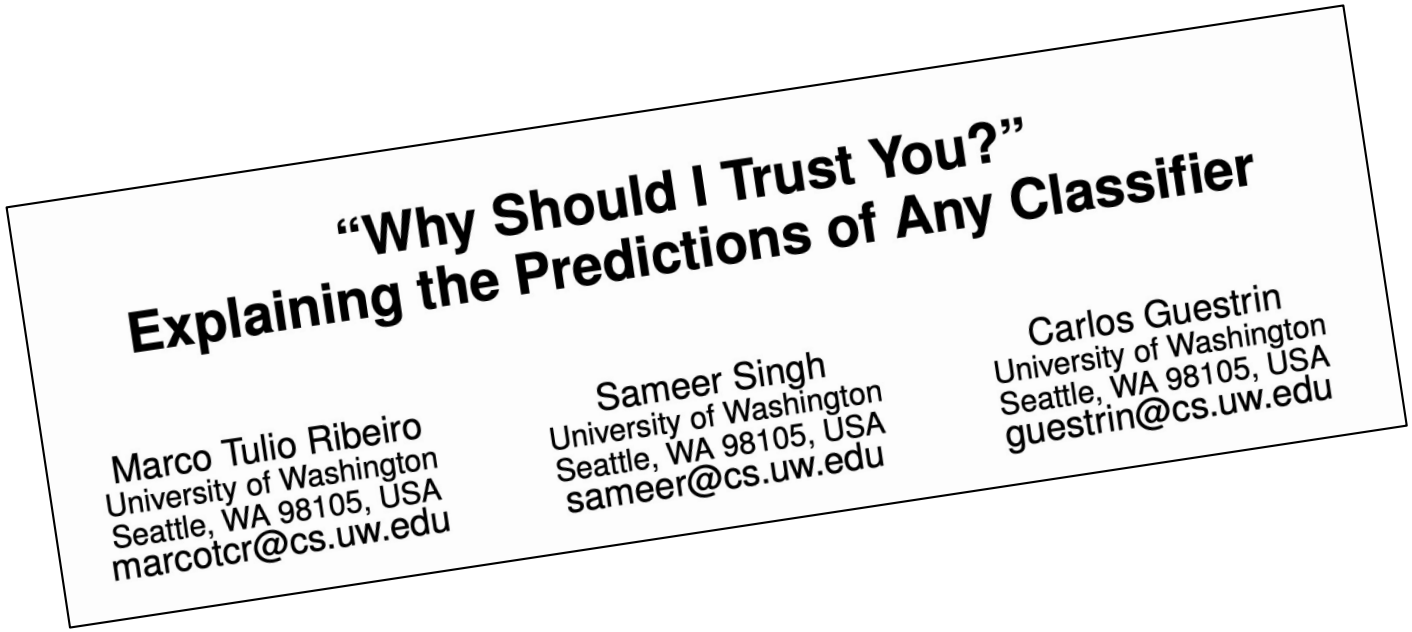
Explainable AI
xAI



"Why Should I Trust You?"
Explaining the Predictions of Any Classifier

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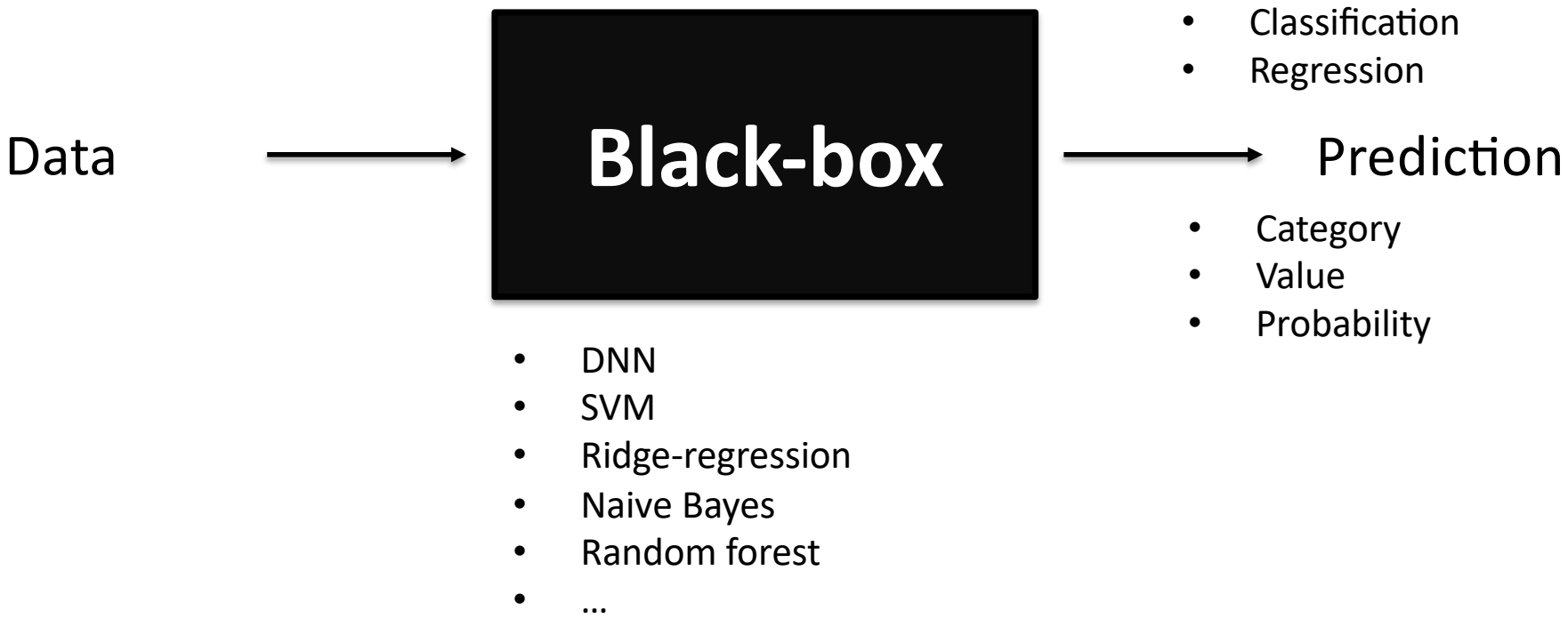
The problem



What is the black box doing, using?
Should we trust it?

Why explaining AI?

- Because!
- Ethics
- Security
- Fairness
- Efficiency

A brief overview (1/4)

- **Purposes of xAI**
  - Create white box interpretable model
  - Explain black-box/complex-model (post-hoc)
  - Enhance fairness of a model
  - Test sensitivity of predictions

A brief overview (2/4)

- **Model specific vs. Model agnostic**
  - Model-specific methods can only be applied to a single model or a group of models
  - Model agnostic methods can be applied to any kind of model

A brief overview (3/4)

- **Local vs. Global explanations**
  - **Local method:** explaining a model for a single decision
  - **Global method:** explaining a model globally

A brief overview (4/4)

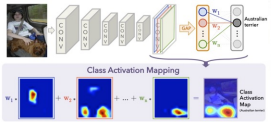
- **Data type**
  - Image
  - Text
  - Sound
  - …

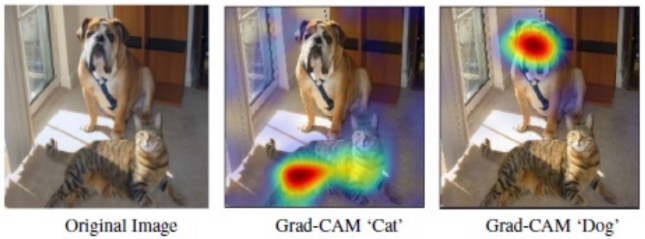
A brief overview (4/4)

- **Grad-cam**

Zhou et al. (2016)
CVPR

Post-hoc explanation
Model specific: CNN only
Local explanation: heatmap on sample
Images / Sound (spectrogram)

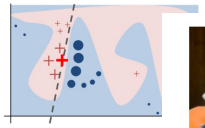


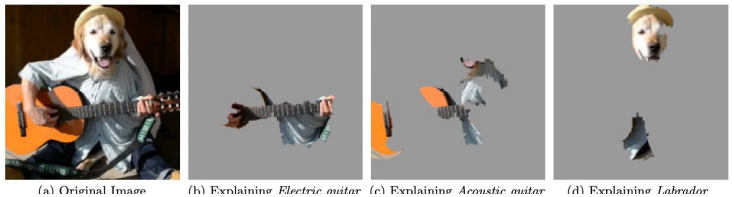


- **LIME**

Ribeiro et al. (2016)
ACM SIGKDD

Post-hoc explanation
Model agnostic
Local explanation: parcelation map
Images / Sound (spectrogram)…



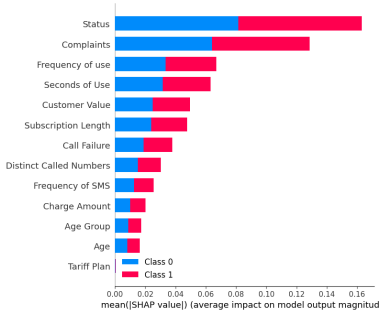


- **SHAP**

Shapley (1951)
The RAND project

Post-hoc explanation
Model agnostic
Global explanation: feature importance map
Any data
Regression or continuous probablity

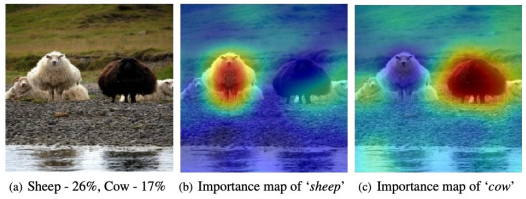
Game theory
« Coalition between players »



- **RISE**

Petsiuk et al. (2018)
BMVC

Post-hoc explanation
Model agnostic
Local explanation: heat map
Images / Sound (spectrogram)…

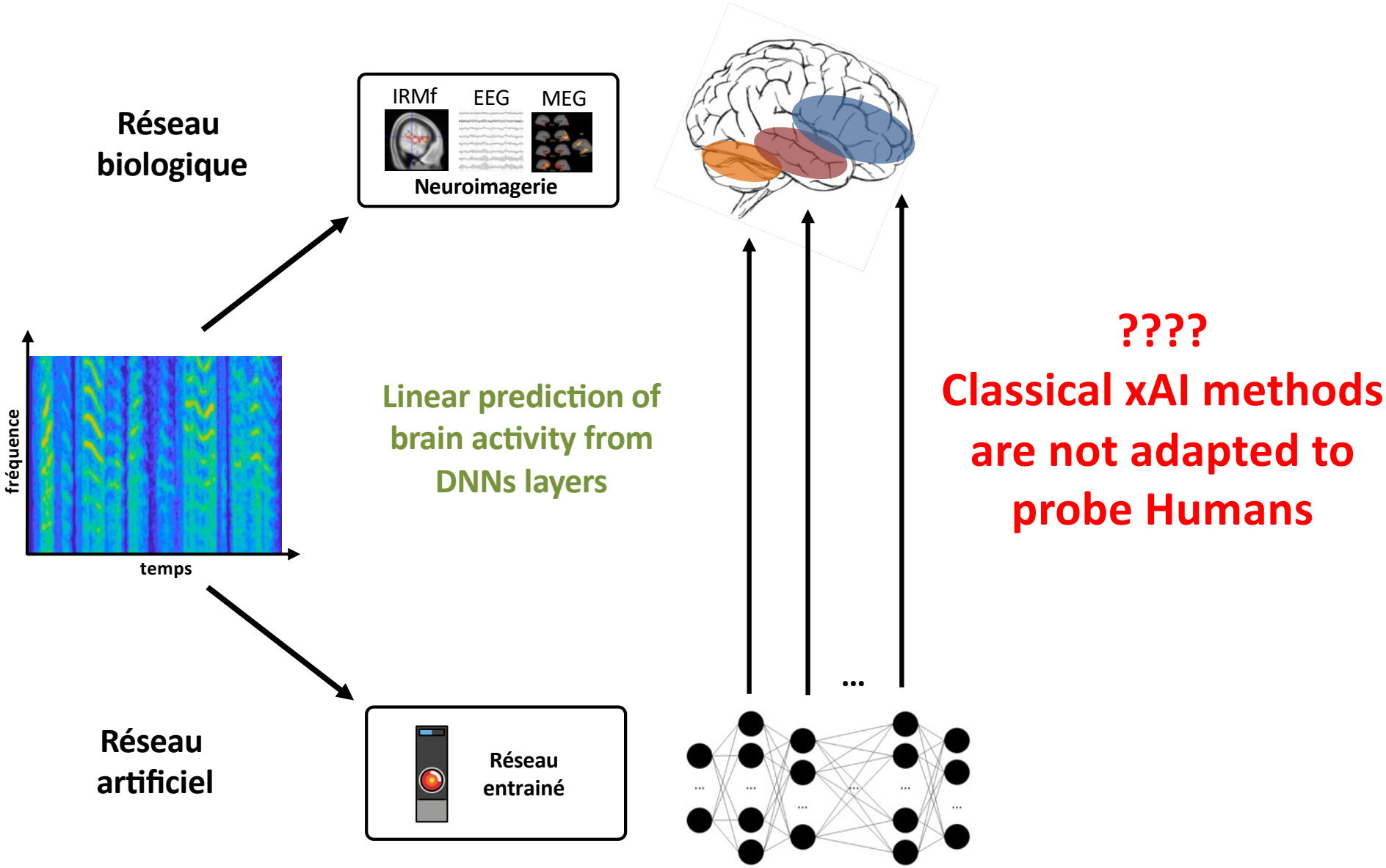


Limitations (1/2)

- We need samples from the training or the testing set
- No underlying model
- Not necessarily applicable to neuroscientific problems

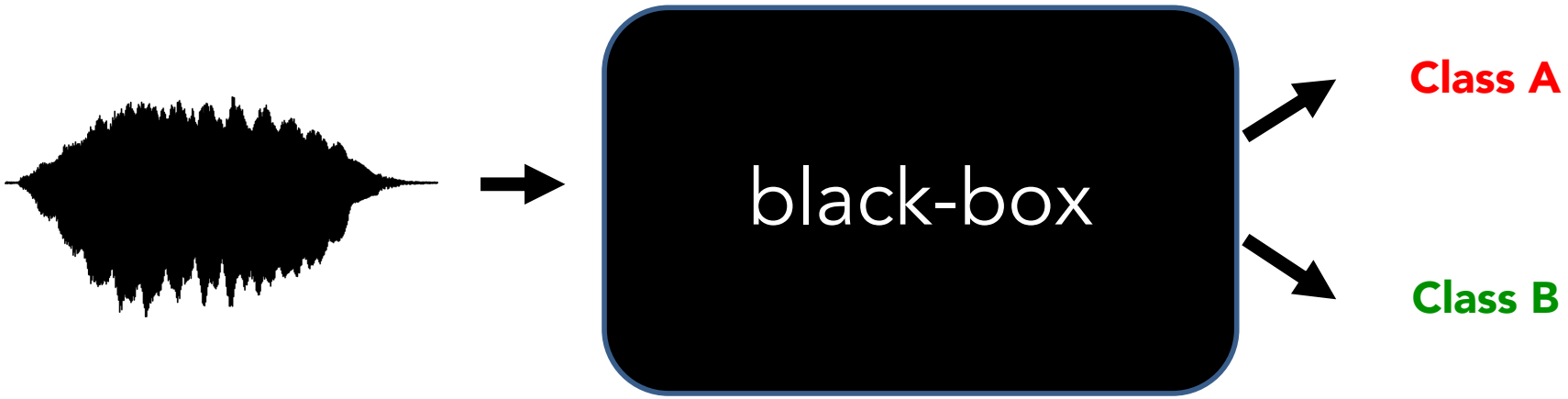
e.g., plausibility of Artificial Networks

Limitations (2/2)



Explaining AI as we probe cognition

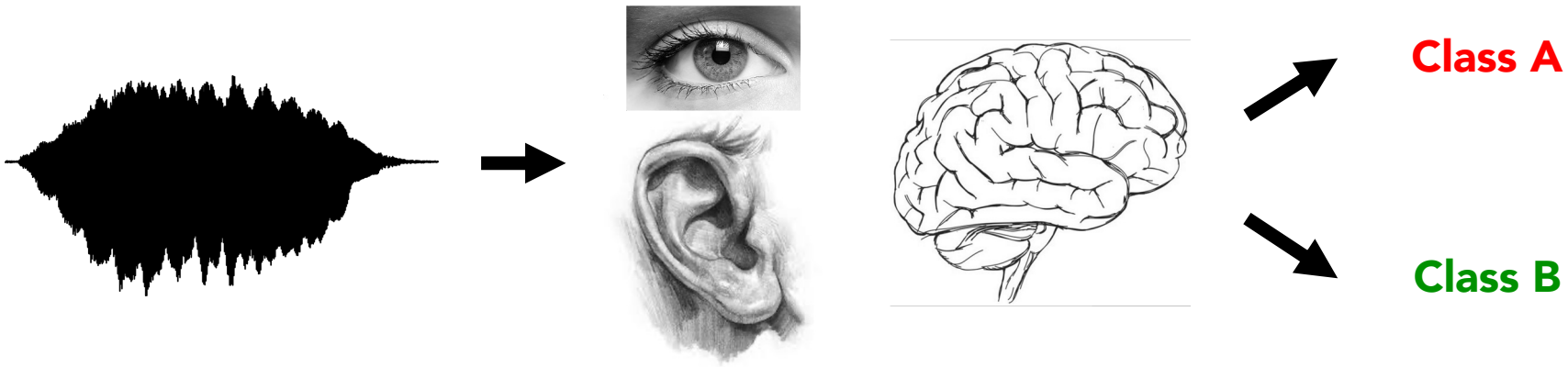
- **Motivation**



What is the black box doing?

Explaining AI as we probe cognition

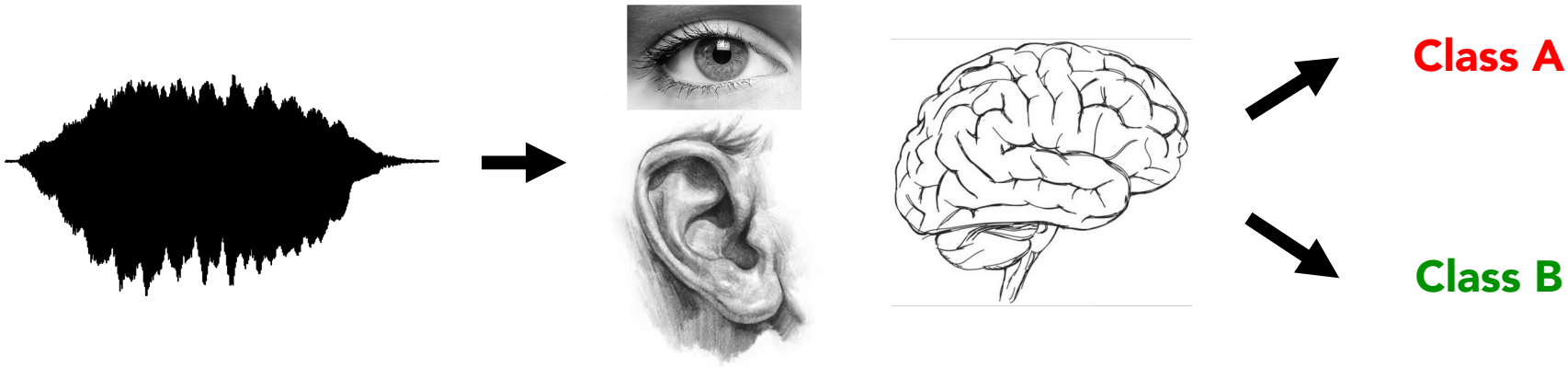
- **Motivation**



What is
the brain
doing?

Explaining AI as we probe cognition

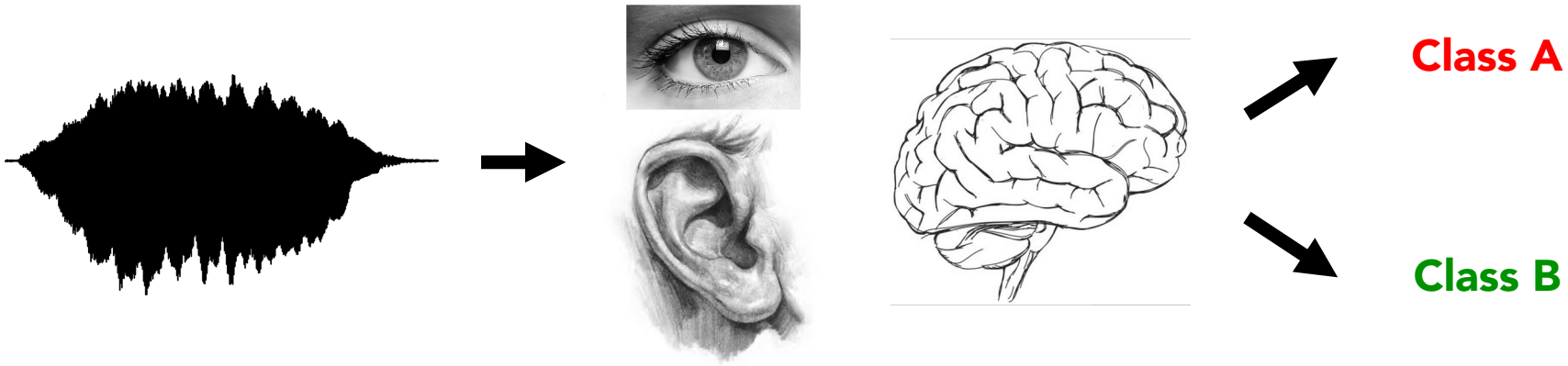
- **Motivation**



Psychophysical experiments on human participants

Explaining AI as we probe cognition

- **Motivation**



Psychophysical experiments on human participants

Bubbles method

Gosselin & Shyns (2001) *Vision Research*

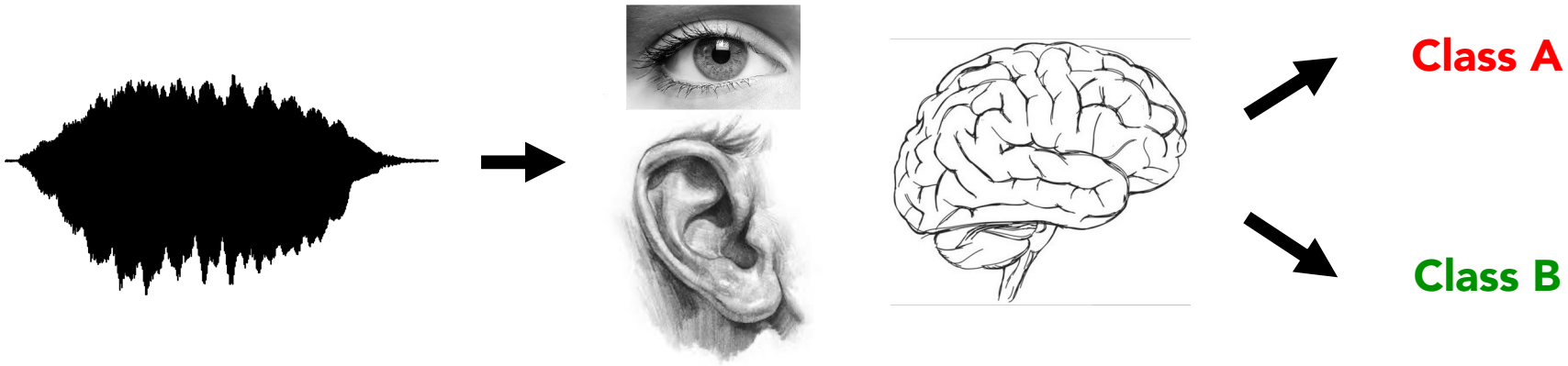
Reverse correlation

Ahumada & Lovell (1971) *J Acoust Soc Am*

Thoret, E., Andrillon, T., Leger, D., Pressnitzer, D. (2021)
Probing machine-learning classifiers using noise, bubbles, and reverse correlation
J. Neuro Methods

Explaining AI as we probe cognition

- **Method**



Idea

- Additive (revcor) or multiplicative (bubbles) noise at the input to fool the subject

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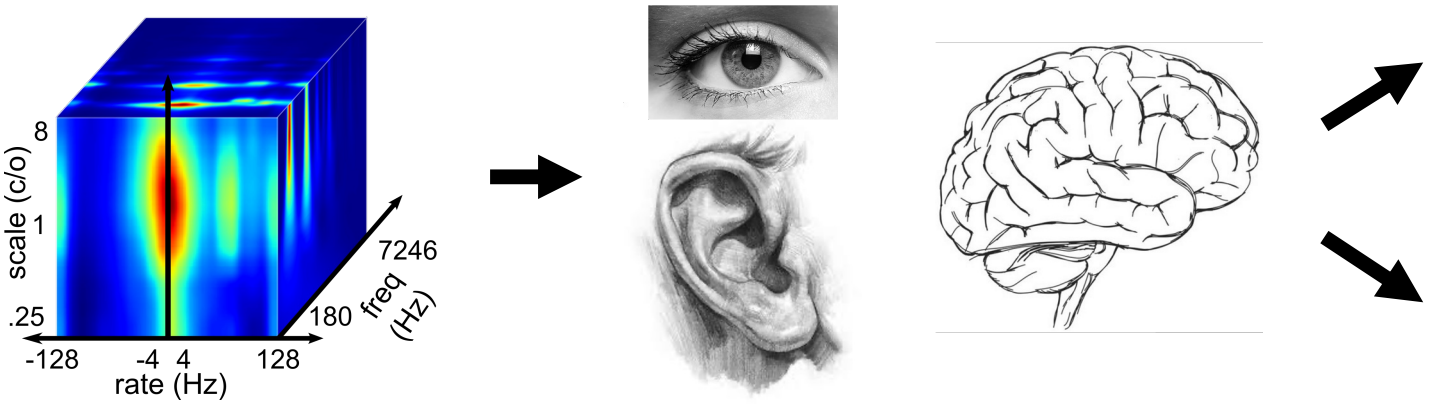

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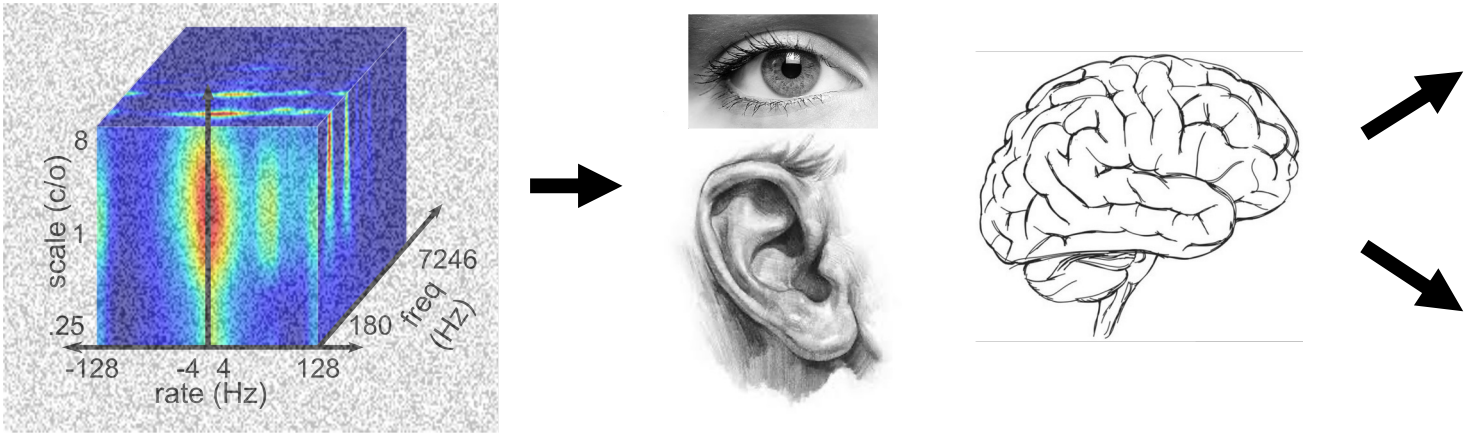

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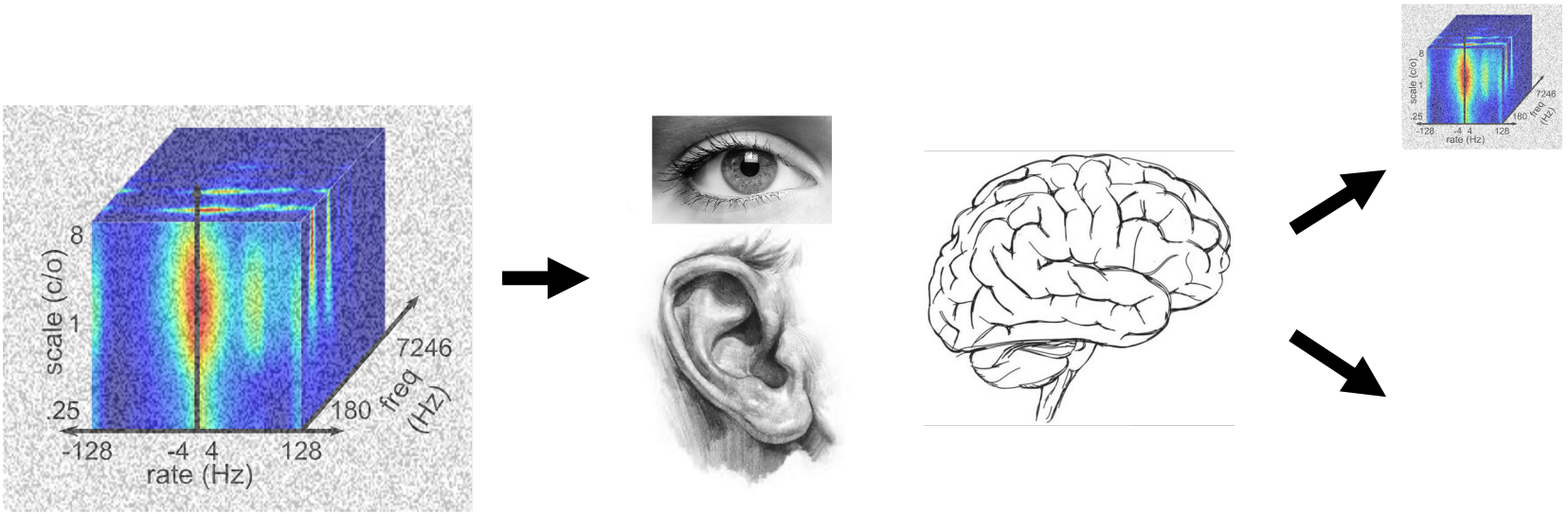

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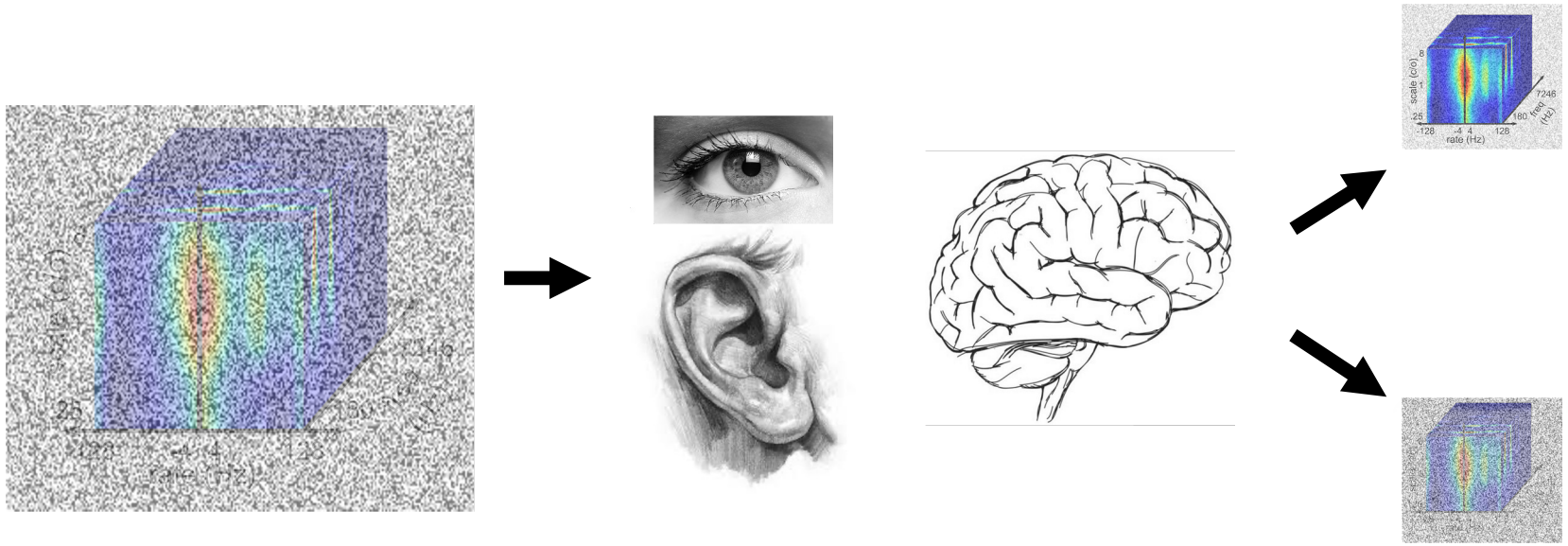

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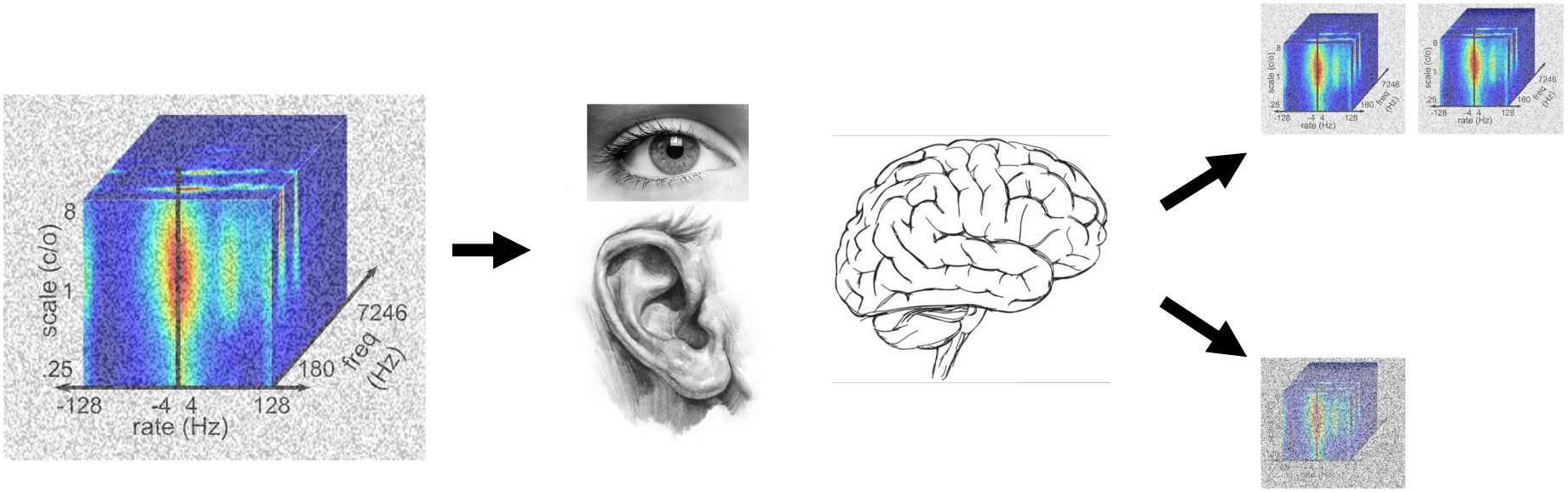
Explaining AI as we probe cognition



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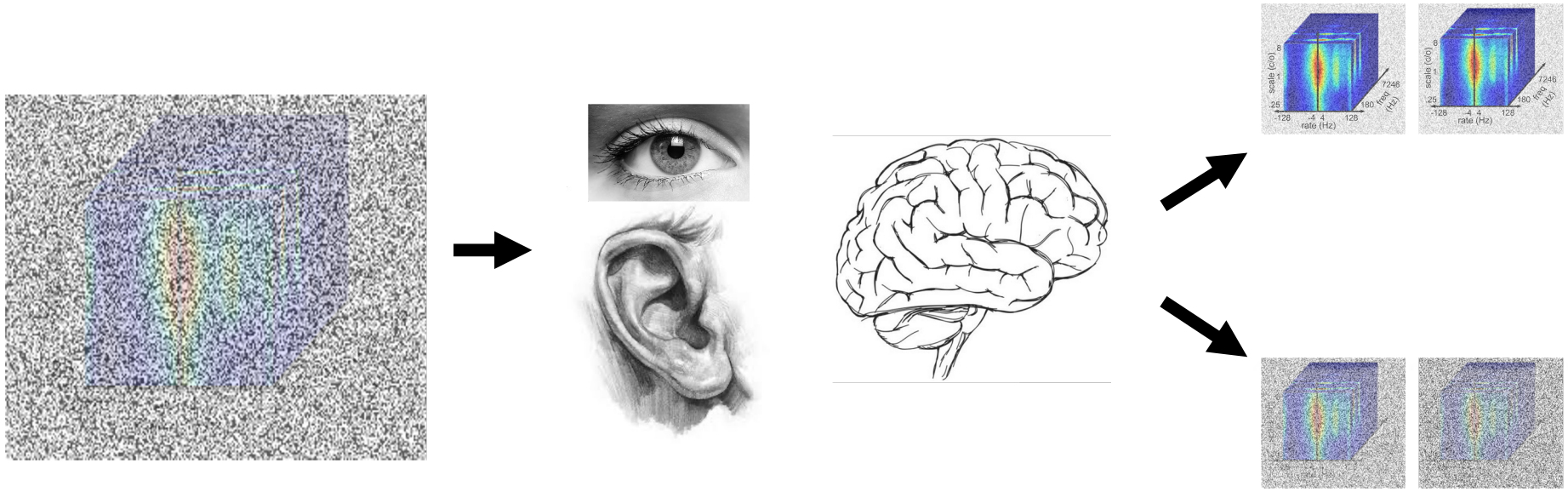

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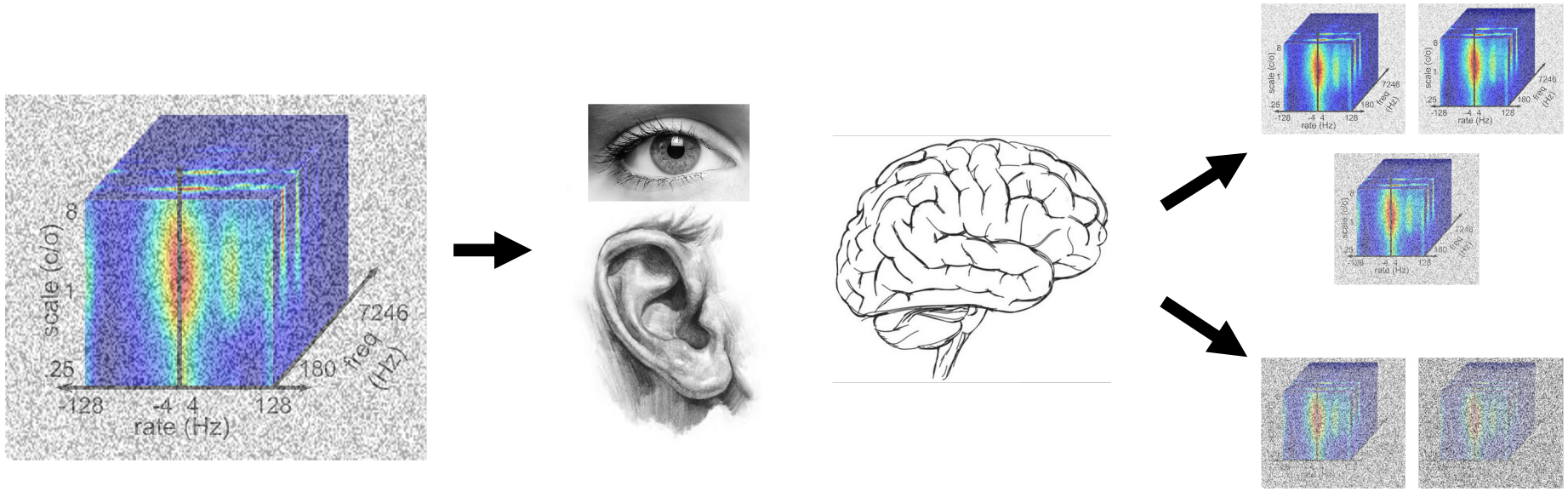

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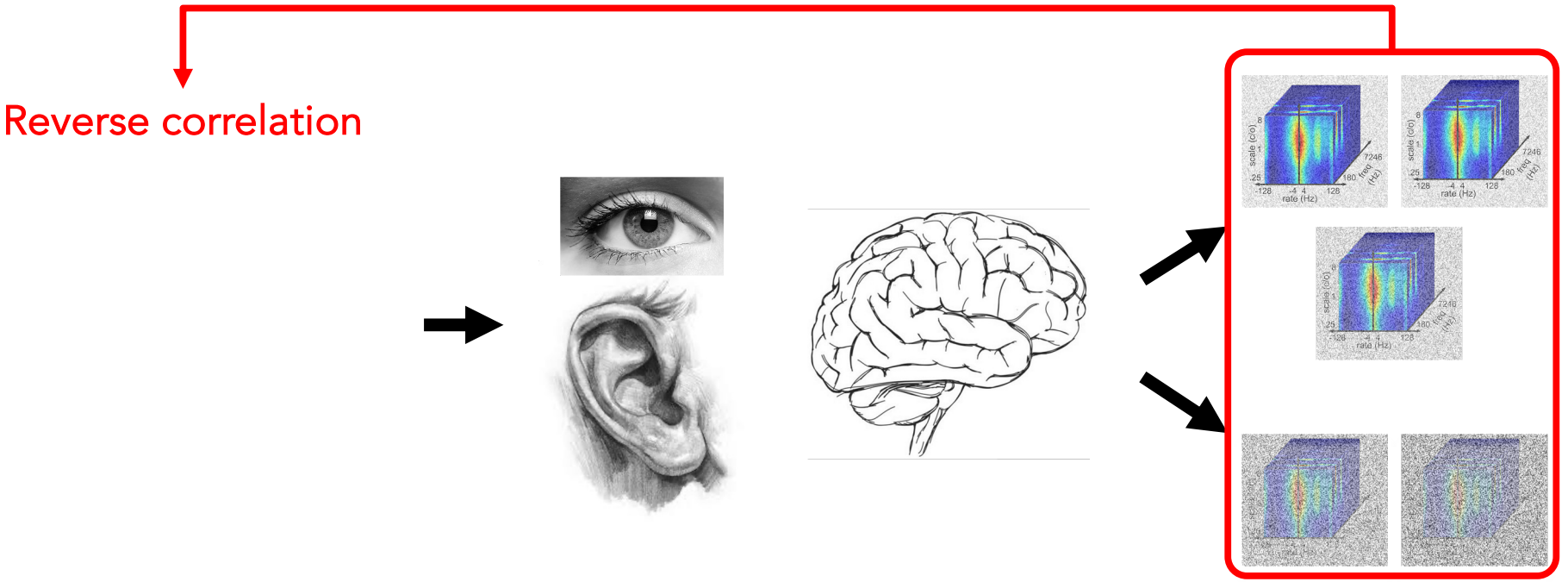

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Analysis

- **using the confusions** of the classifier to determine

Thoret, E., Andrillon, T., Leger, D., Pressnitzer, D. (2021)
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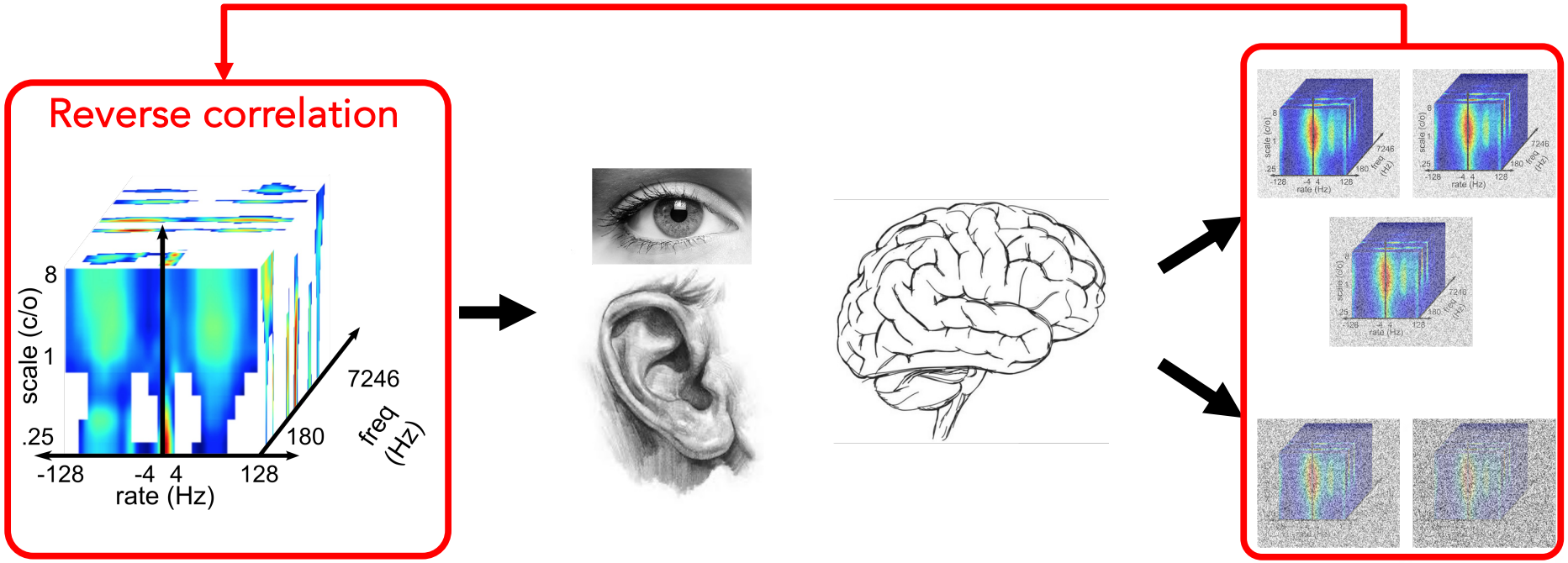
Explaining AI as we probe cognition



Idea

- Additive (revcor) or multiplicative (bubbles) noise at the input to fool the subject

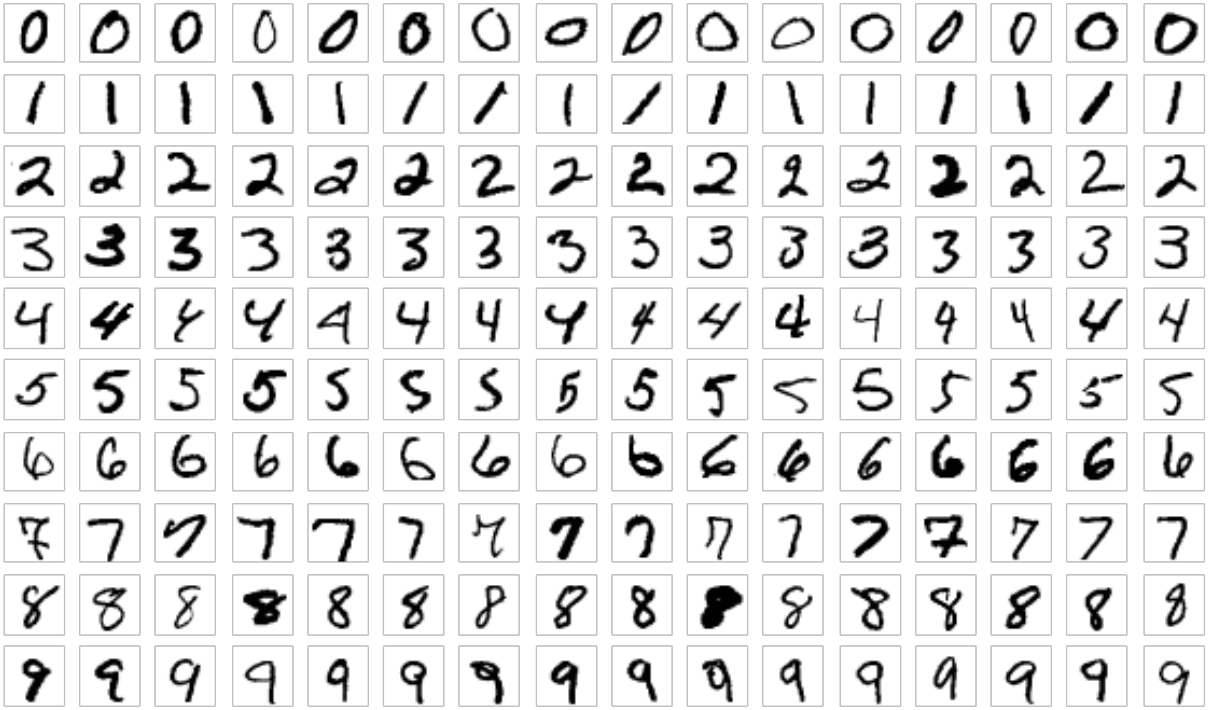
Analysis

- **using the confusions** of the classifier to determine
  which parts of the input are the most important

Thoret, E., Andrillon, T., Leger, D., Pressnitzer, D. (2021)
Probing machine-learning classifiers using noise, bubbles, and reverse correlation
J. Neuro Methods

Two methods:
bubbles and reverse correlation

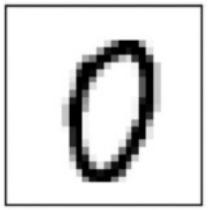
Images from the handwritten digits database
MNIST



Two methods:
bubbles and reverse correlation
toy example

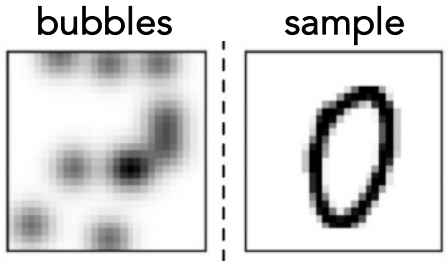
Multiplicative noise

sample



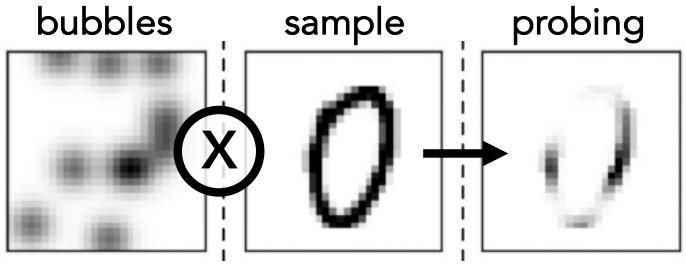
Two methods:
bubbles and reverse correlation
toy example

Multiplicative noise



Two methods:
bubbles and reverse correlation
toy example

Multiplicative noise



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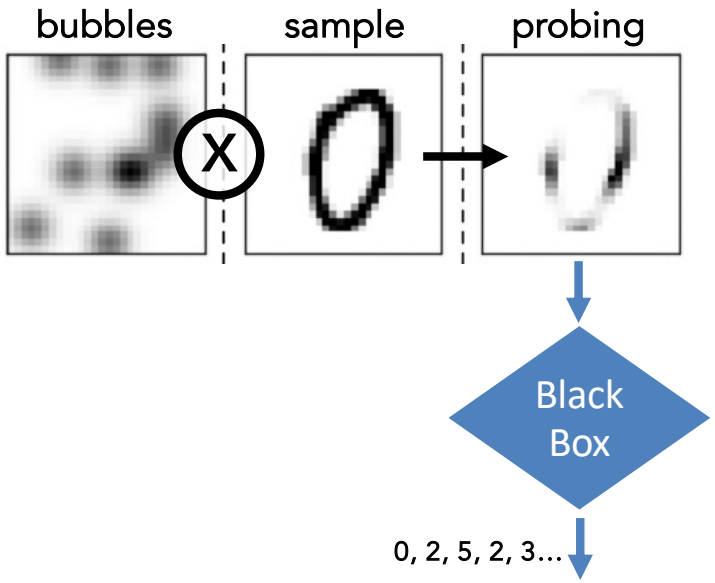
toy example

Multiplicative noise



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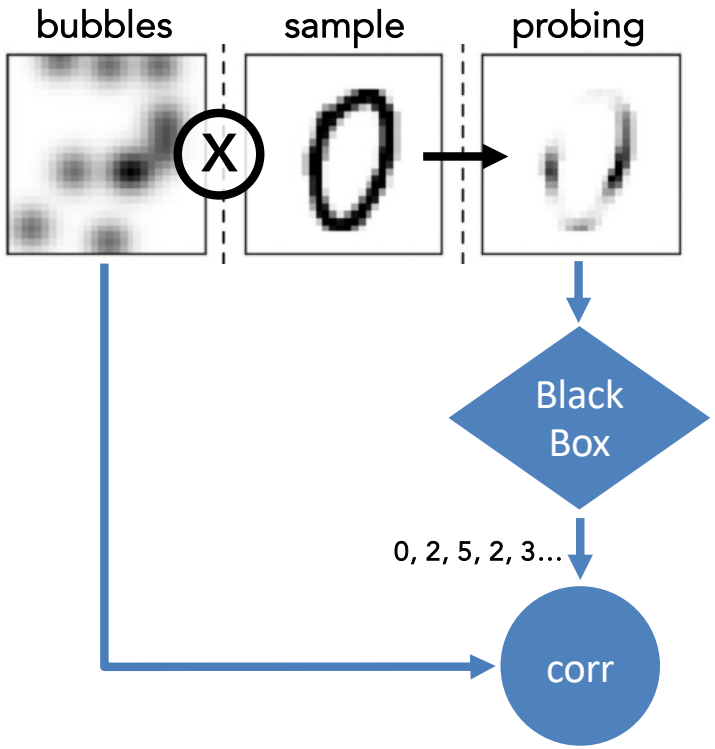
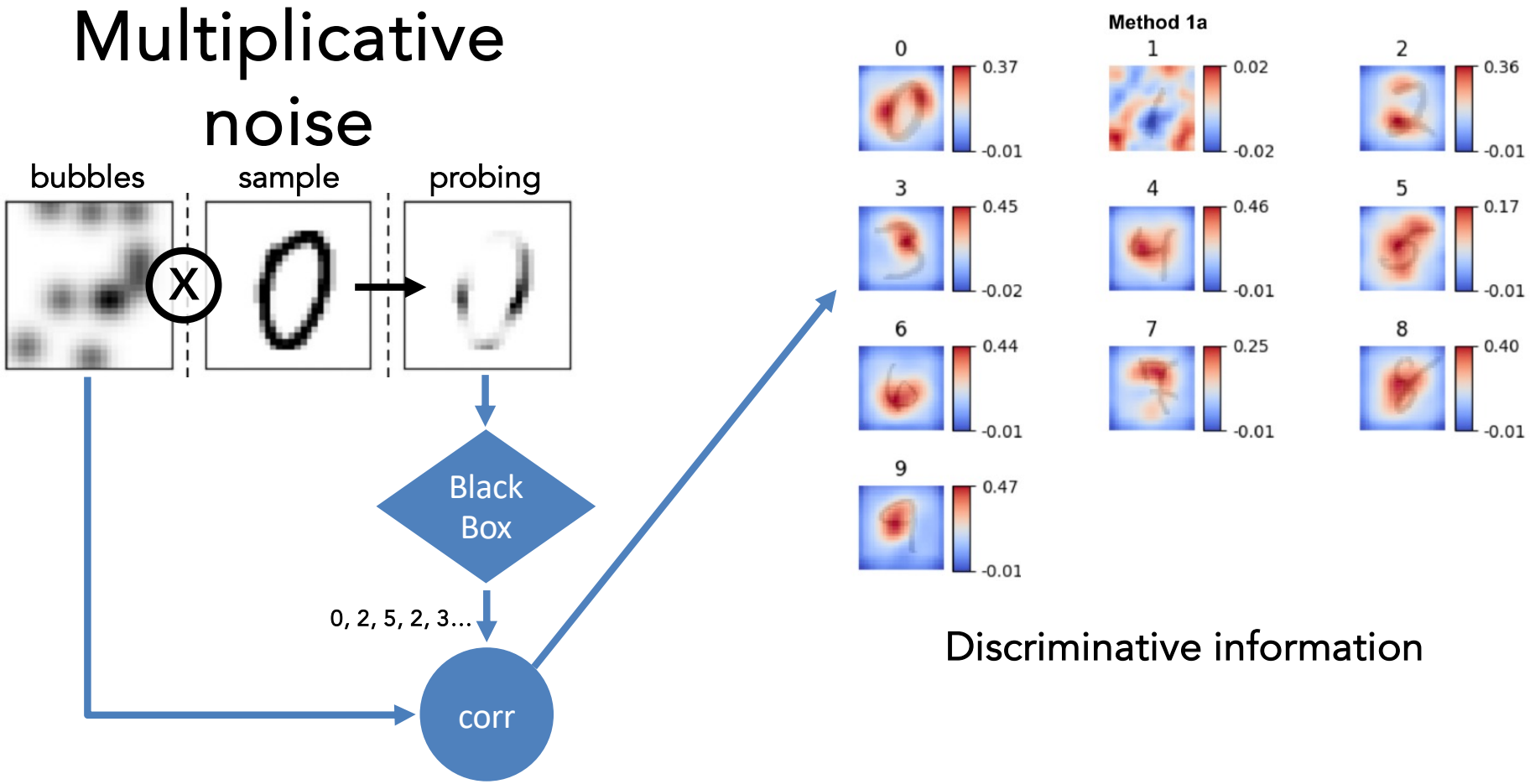
bubbles and reverse correlation
toy example

Multiplicative noise



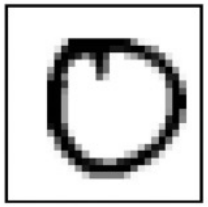
Two methods:
bubbles and reverse correlation
toy example



Two methods:
bubbles and reverse correlation
toy example

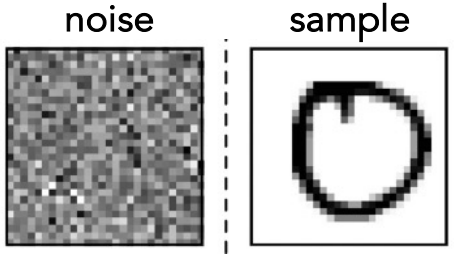
Additive
noise

sample



Two methods:
bubbles and reverse correlation
toy example

Additive noise



Two methods:
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toy example

Additive
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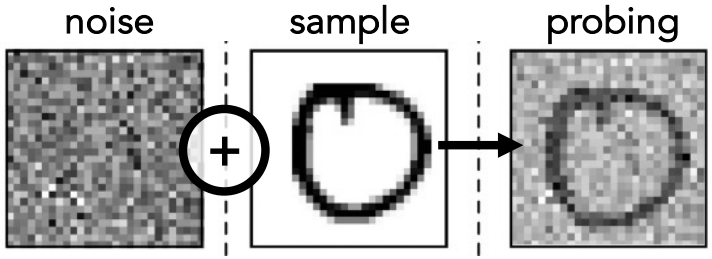
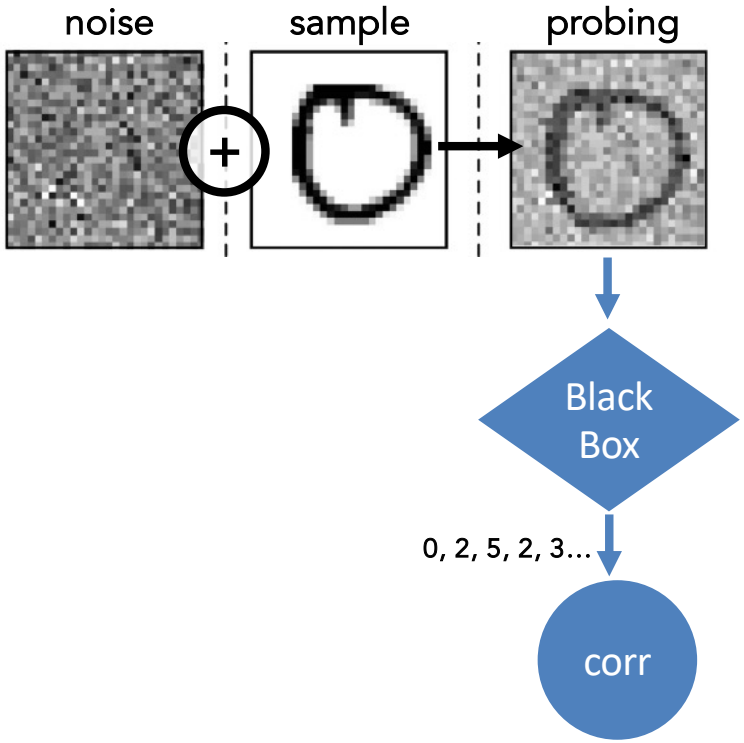


Two methods:
bubbles and reverse correlation
toy example

Additive noise



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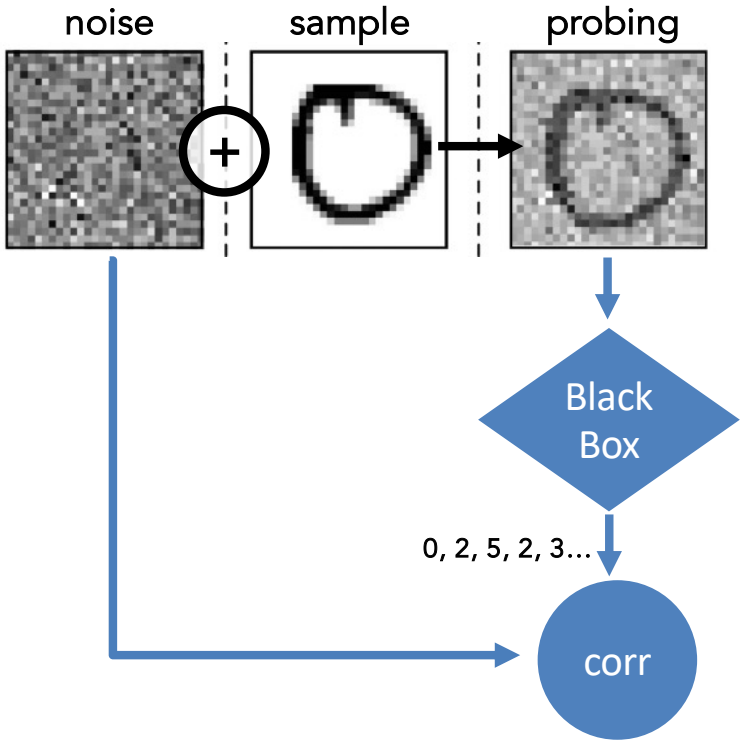
toy example

Additive noise



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toy example

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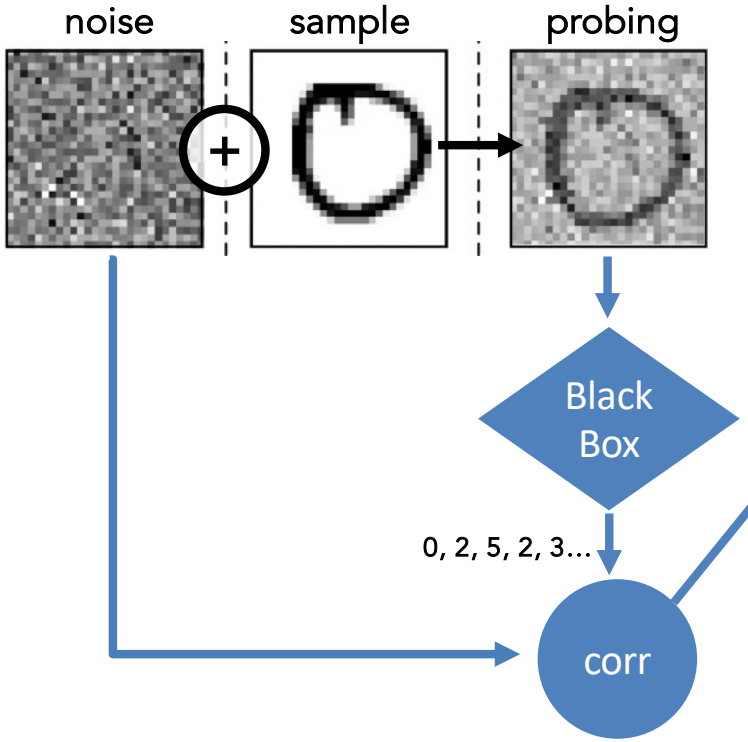

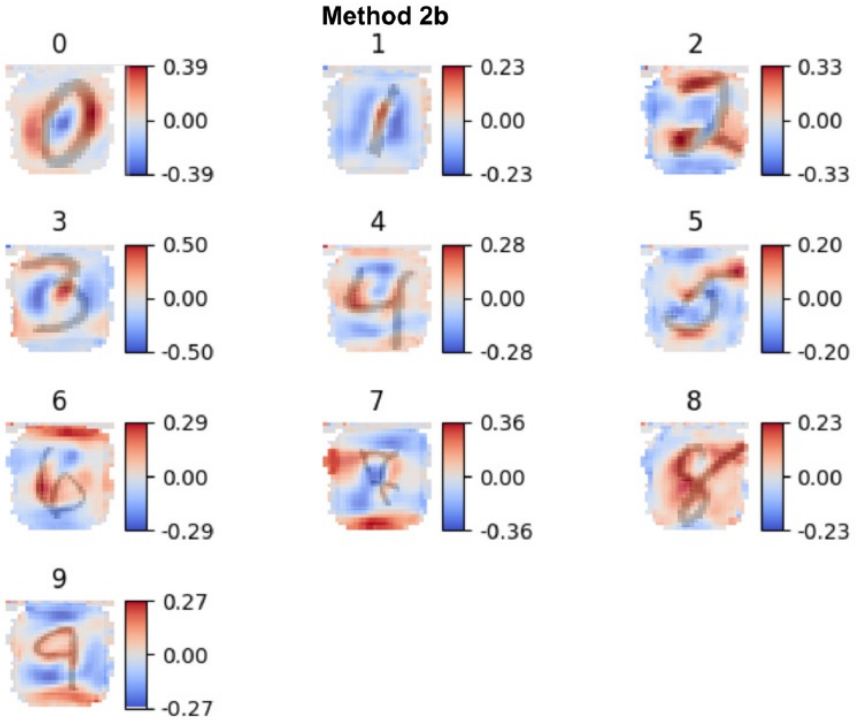

Represented information

« Prototype »

Bubbles in the jungle

Reverse correlation

Vision Research
Volume 44, Issue 5, March 2004, Pages 461-470

Troubles with bubbles

Richard F. Murray [a], Jason M. Gold [b]

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70 Opinion TRENDS in Cognitive Sciences Vol.6 No.2 February 2002

RAP: a new framework for visual categorization

Frédéric Gosselin and Philippe G. Schyns

approach that iso
test its performar
conditions of exp
discoveries about
scene categories,
different recognit
recognition do no
processes of low-l
face, object and s
are not always fir
principles of early
that high- and lov

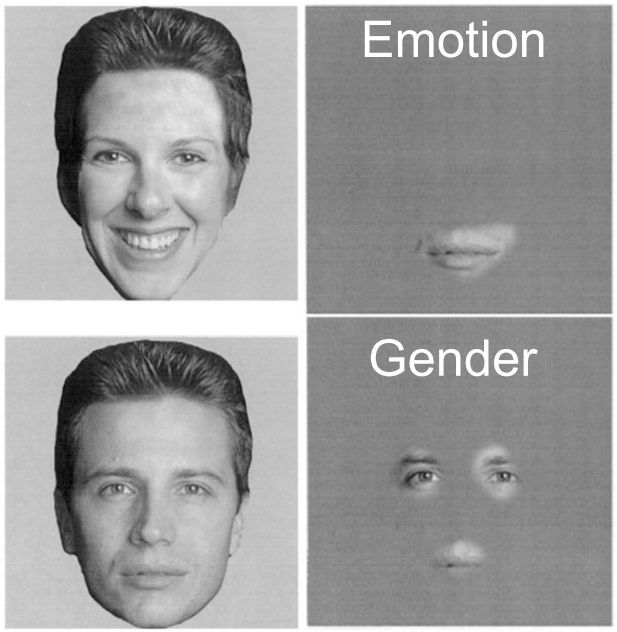
Bubbles

Explaining AI as we probe cognition

- **Example of applications in vision and audition**

Bubbles

Which information are the most important?



Gosselin, F., & Schyns, P. G. (2001).
Vision research, 41(17), 2261-2271.

Reverse Correlation

Which information are « stored in memory? »

Dotsch, R., & Todorov, A. (2012).
Social Psychological and Personality Science, 3(5), 562-571.

Explaining AI as we probe cognition

- **Example of applications in vision and audition**

Bubbles: analysis of the spatio-temporal course of visual identification of a face

What visual areas do we focus on to identify a face and how does this change over time?

- "dynamic" bubbles

Explaining AI as we probe cognition

- **Example of applications in vision and audition**

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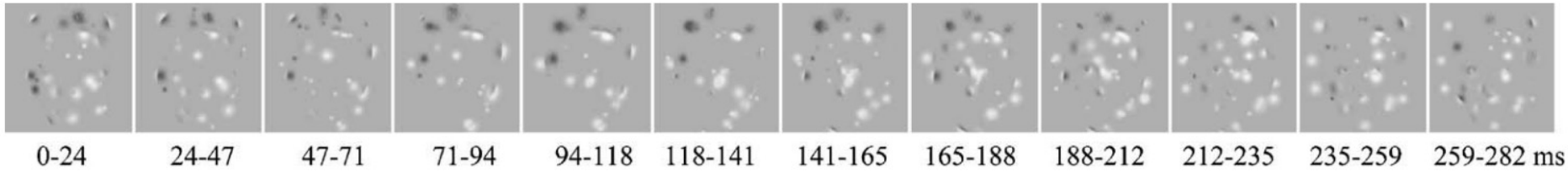

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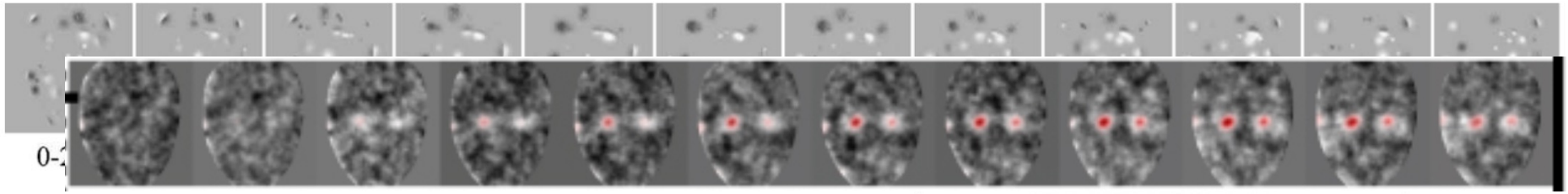

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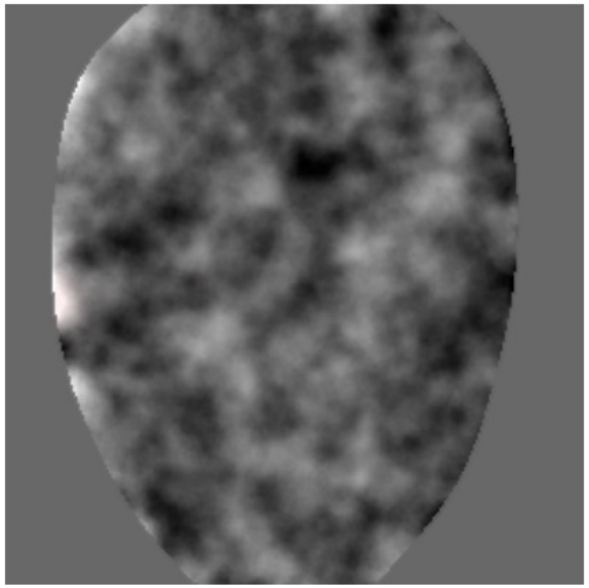

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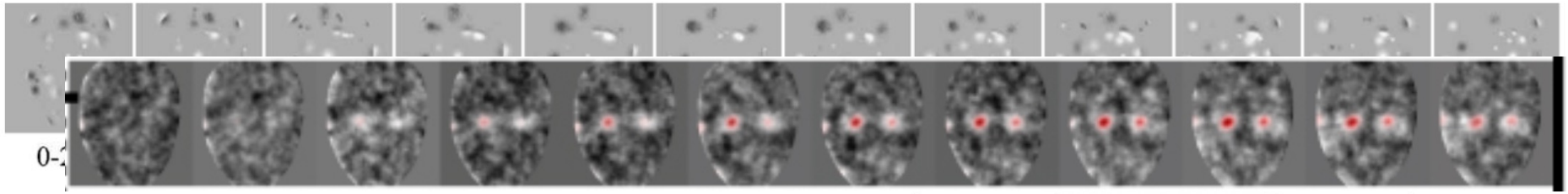

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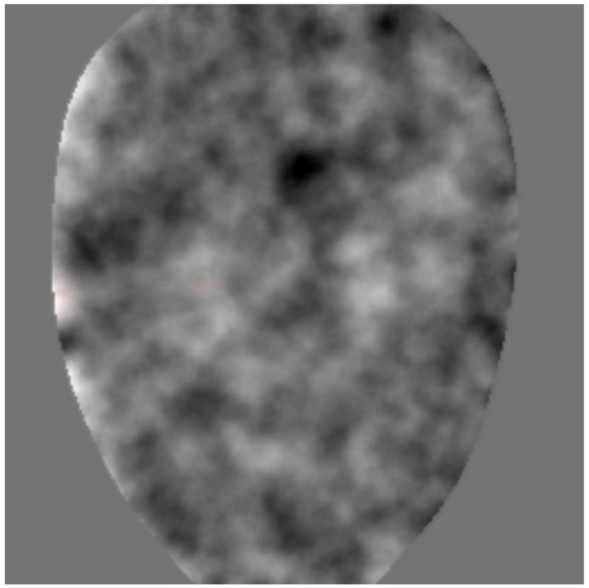

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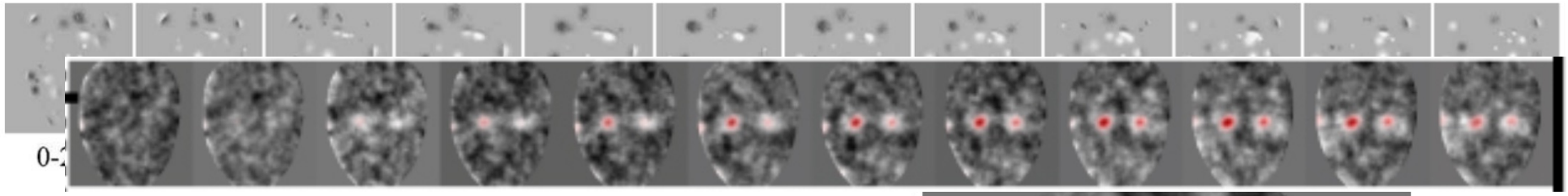

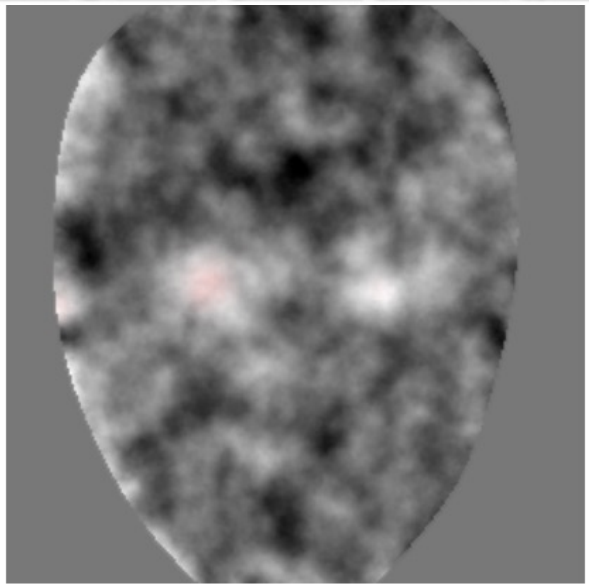

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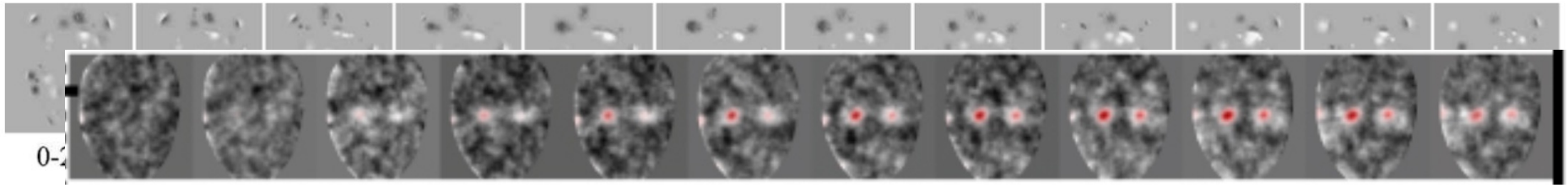

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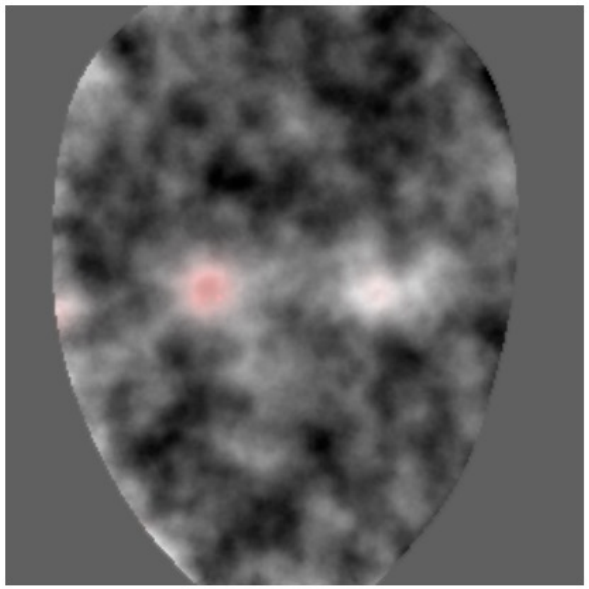

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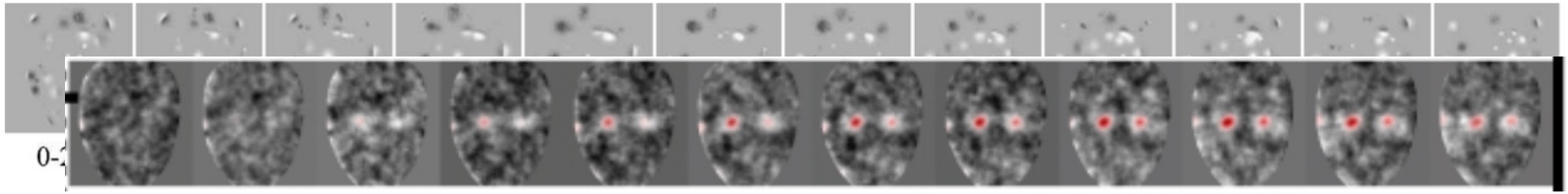

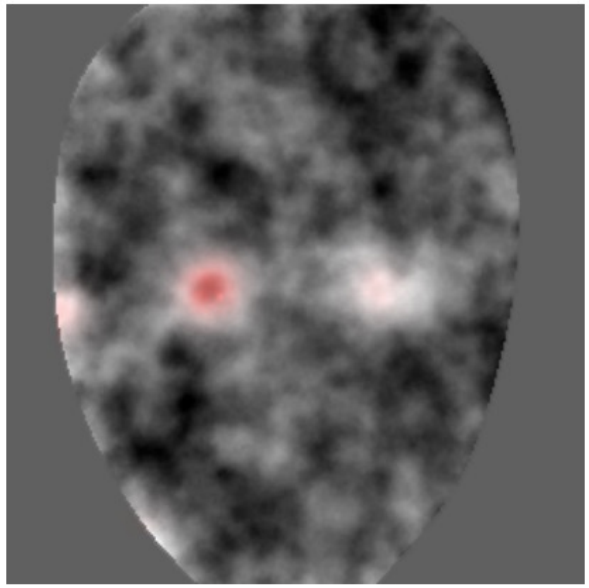

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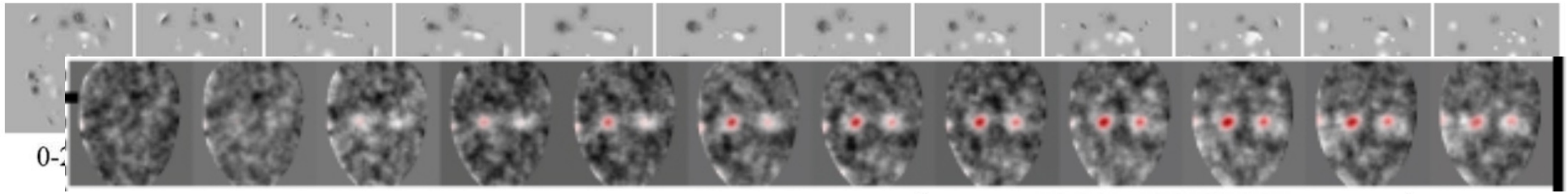

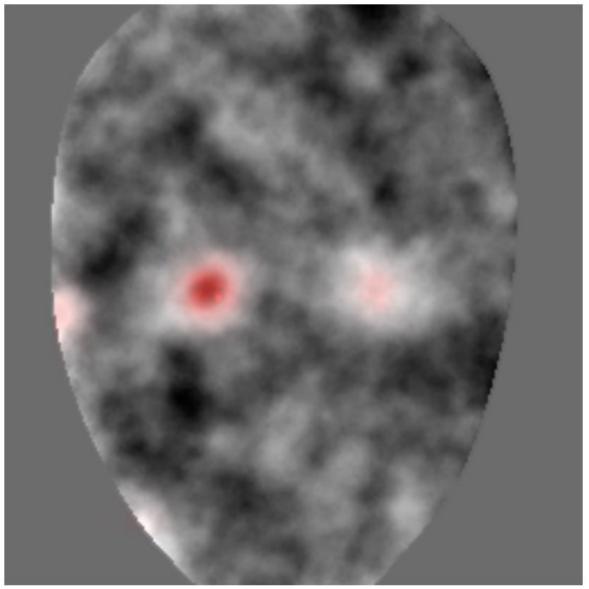

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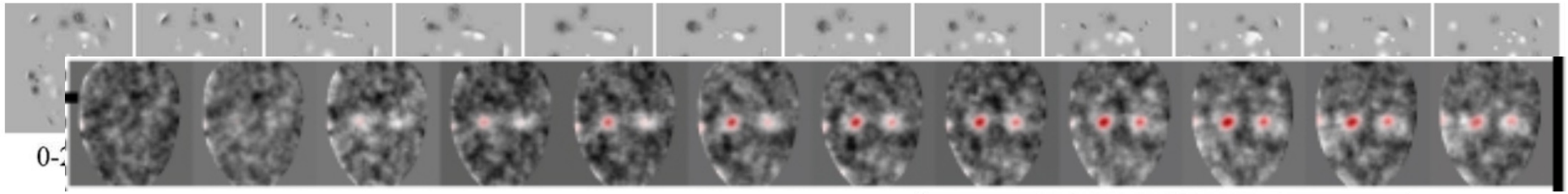

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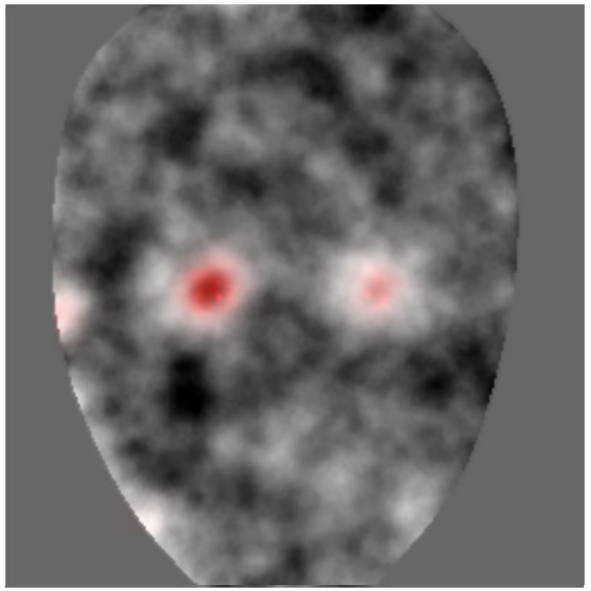

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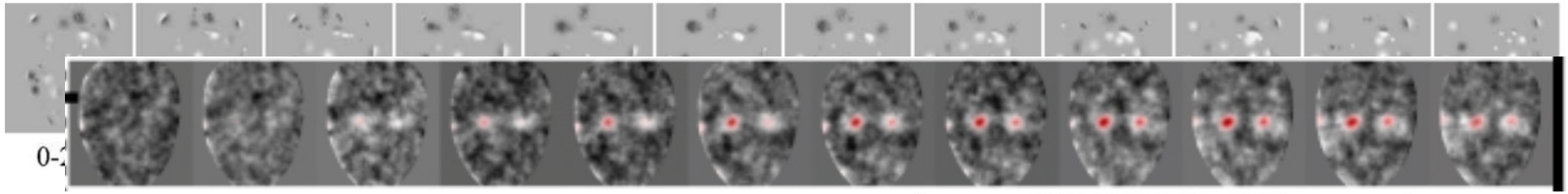

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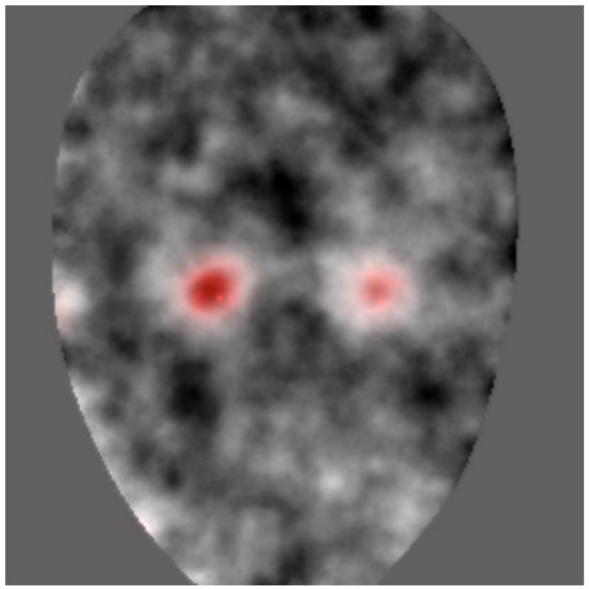

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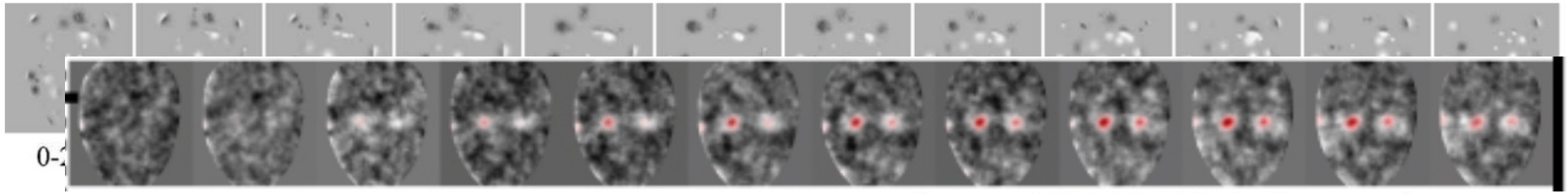

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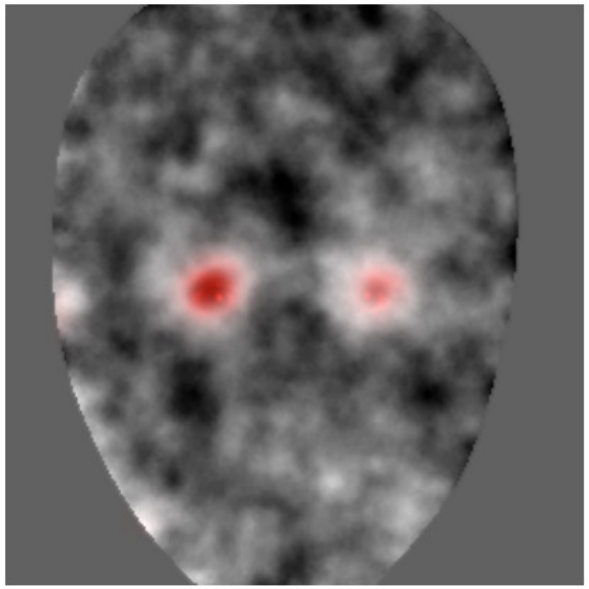

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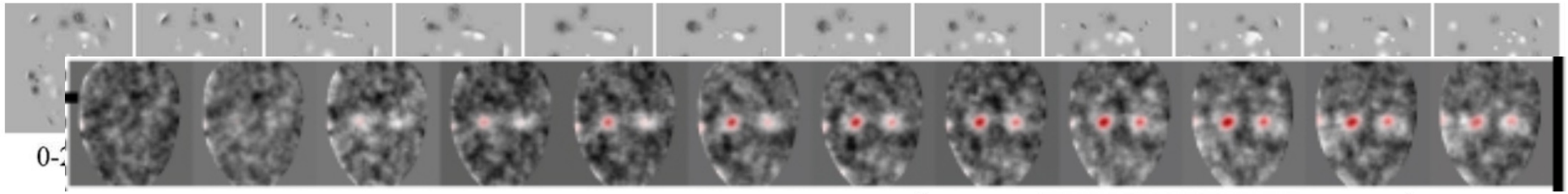

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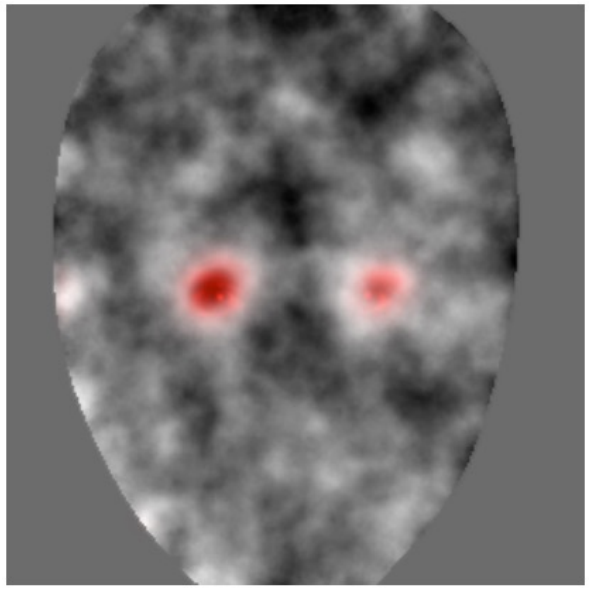

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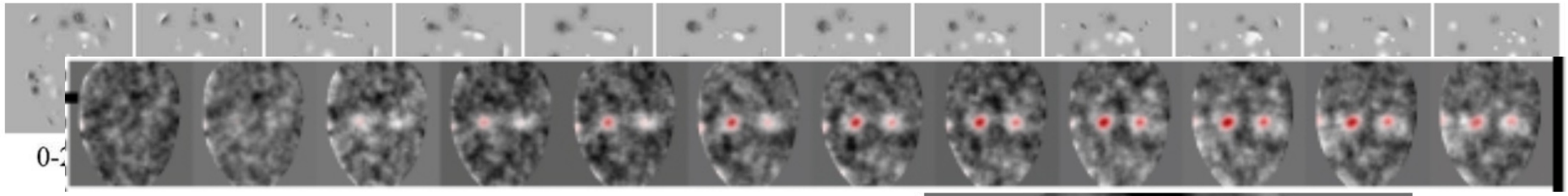

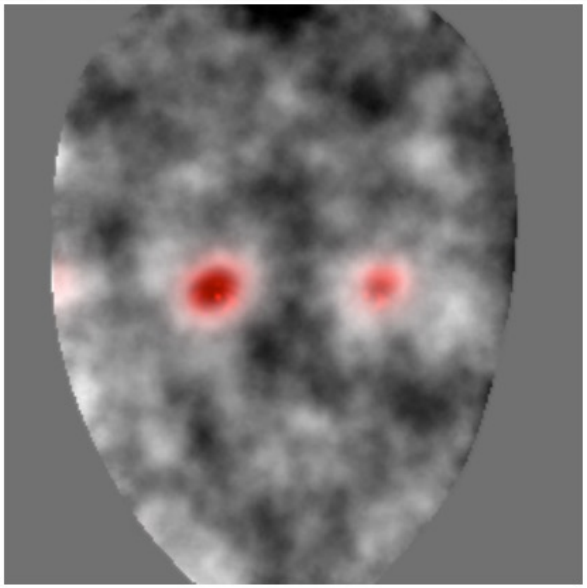

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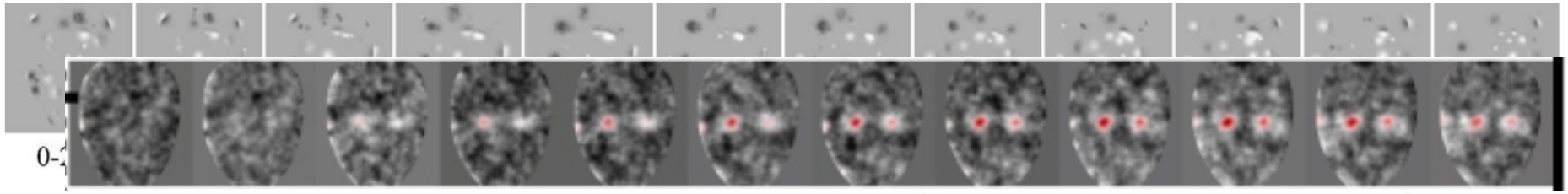

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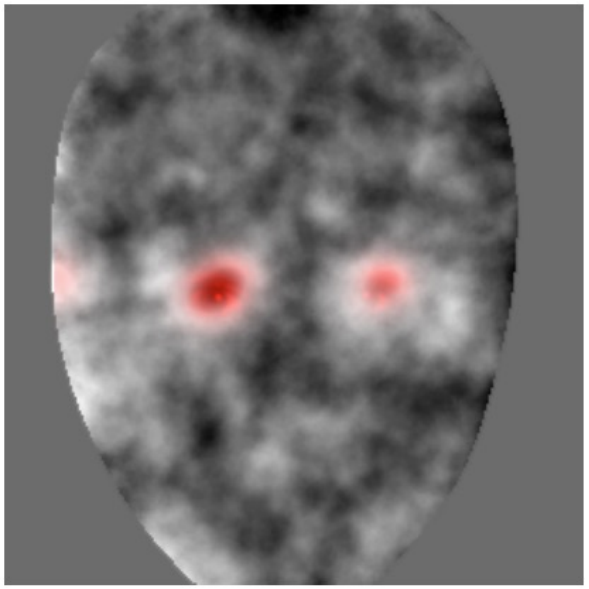

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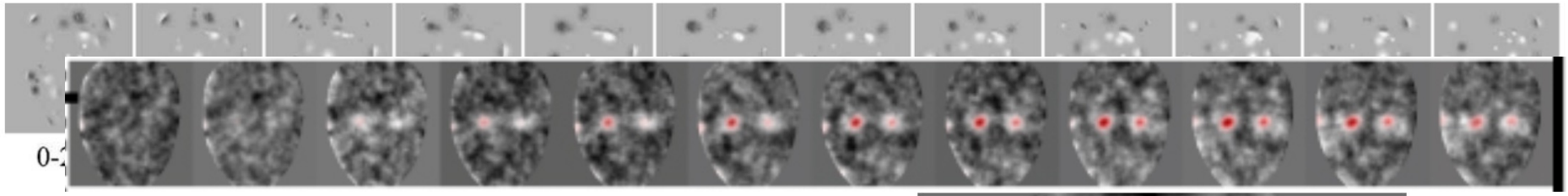

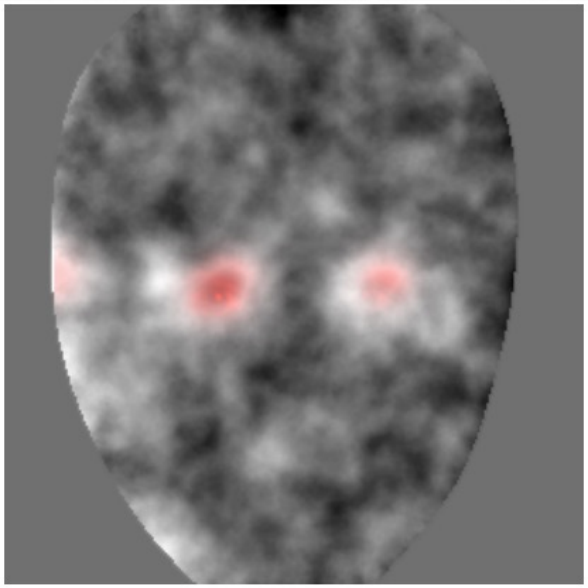

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Comparison with pigeons!

Journal of Experimental Psychology:
Animal Behavior Processes
2005, Vol. 31, No. 3, 376–382

0097-7403/05/$12.00 DOI: 10.1037/0097-7403.31.3.376

Applying Bubbles to Localize Features That Control Pigeons' Visual Discrimination Behavior

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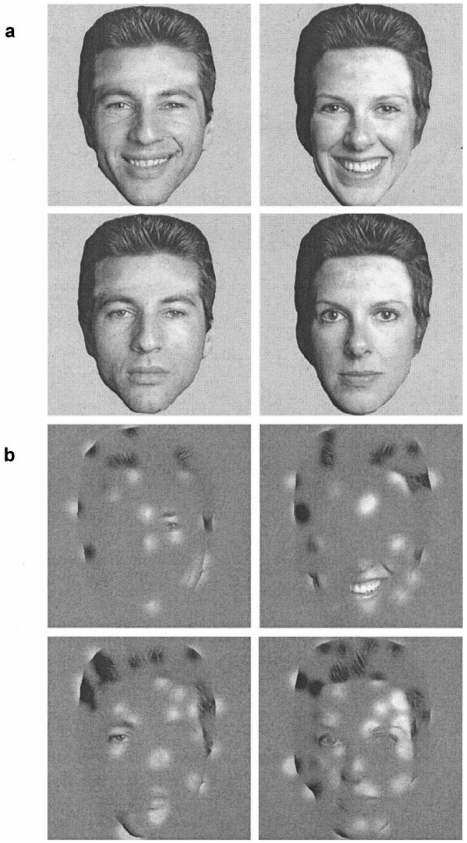
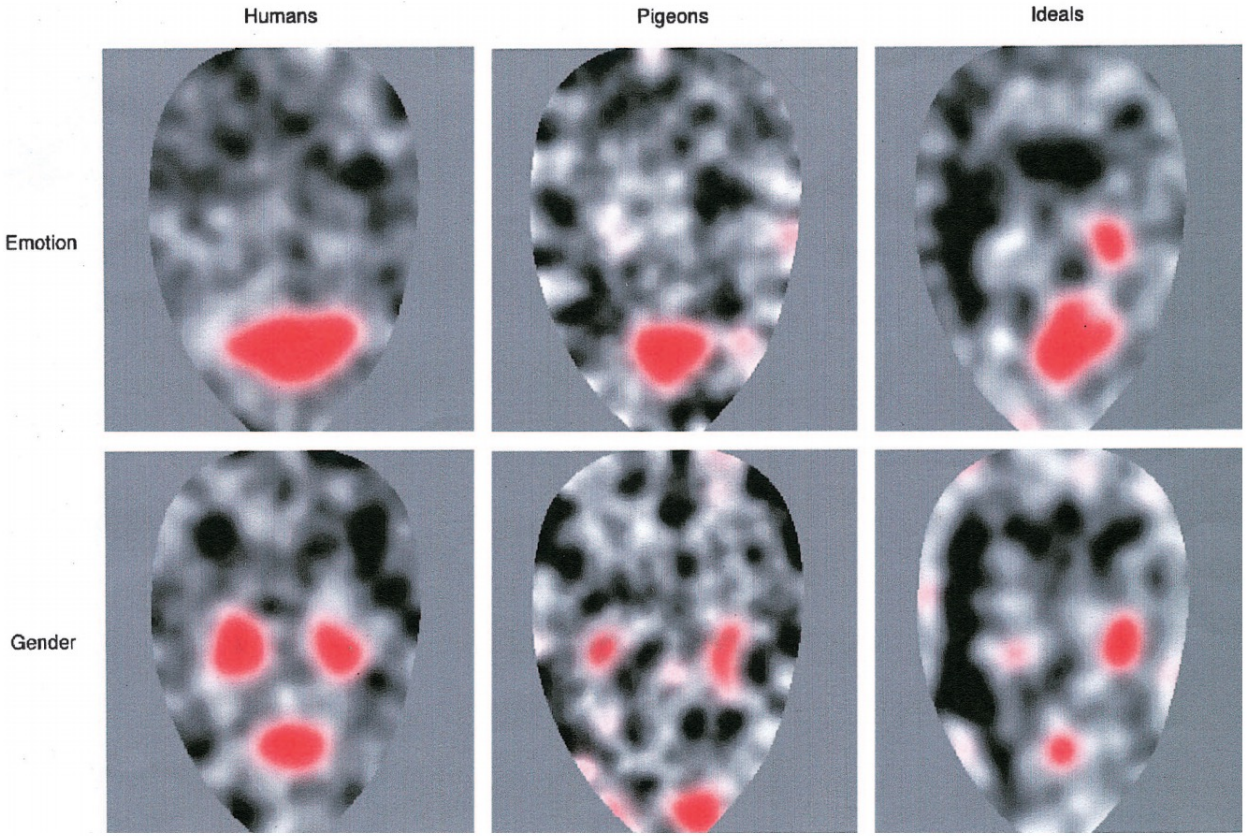
The University of Iowa

Frédéric Gosselin
Université de Montréal

Philippe G. Schyns
University of Glasgow





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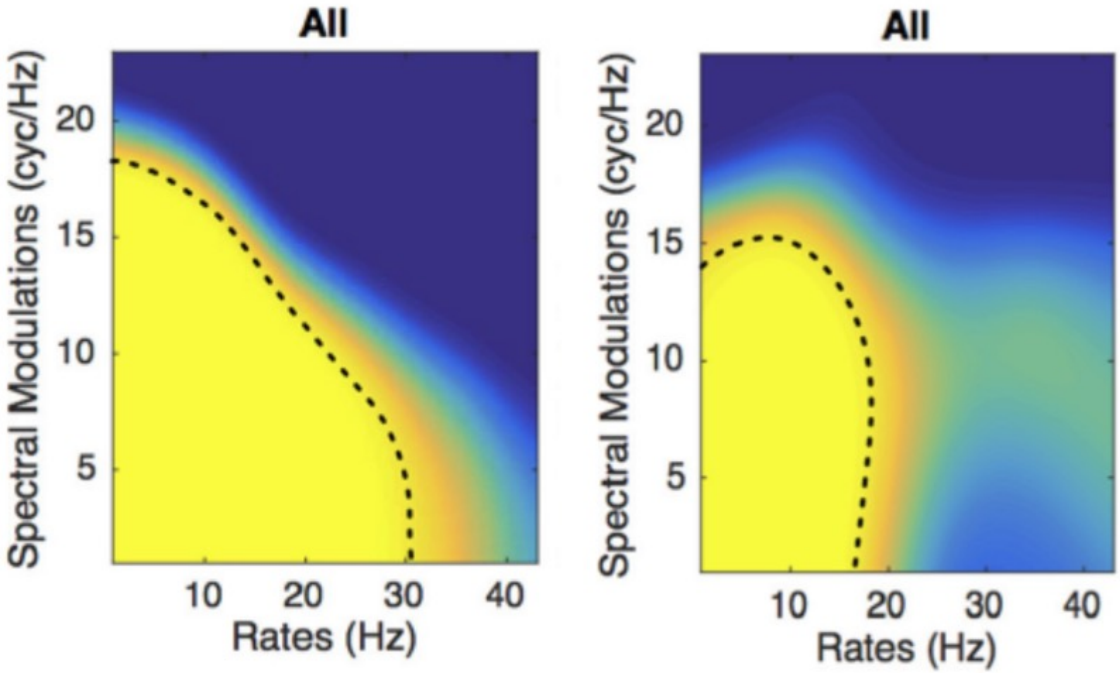
Spectro-temporal modulations the most relevant for musical instrument timbre identification



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bubbles

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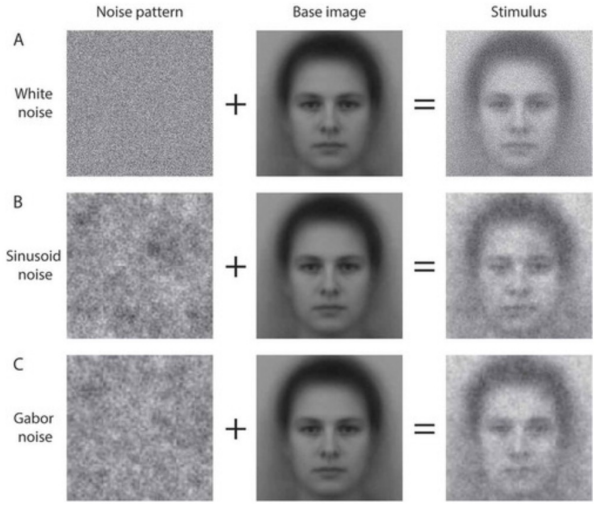
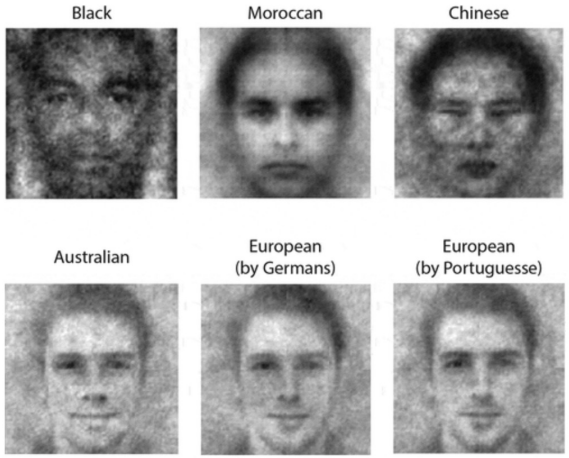
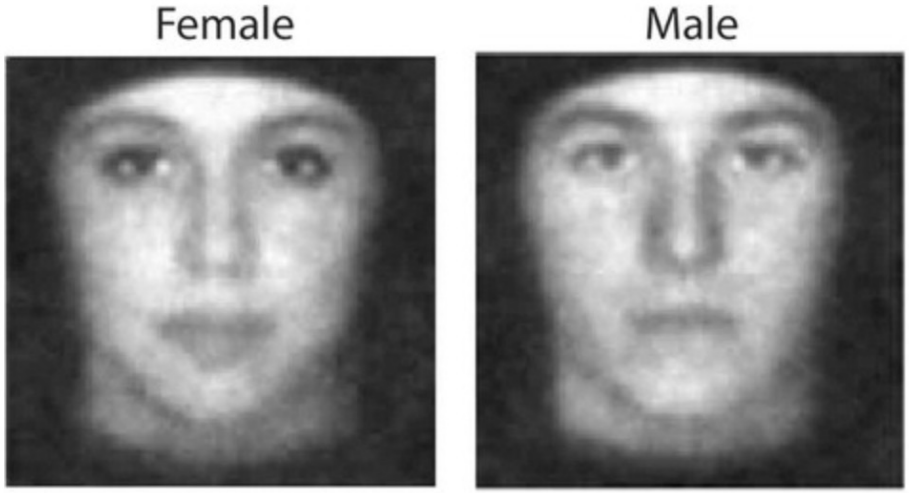




Social cognition



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What makes Mona Lisa smile?

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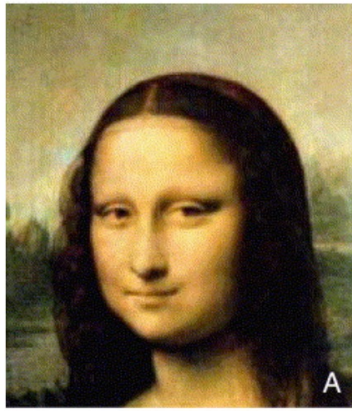

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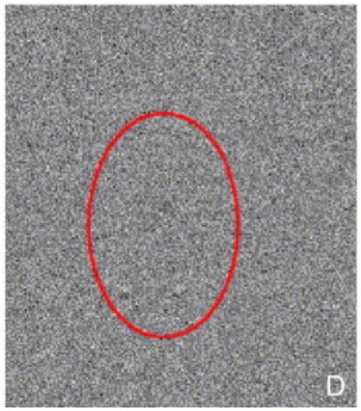

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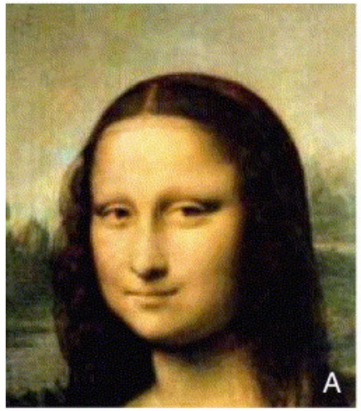
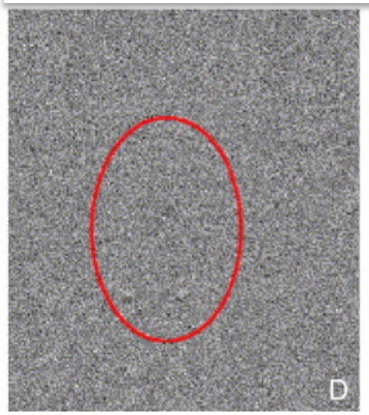
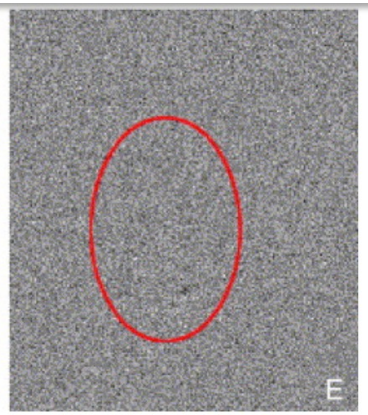
Two additive masks



Smiling



Non Smiling



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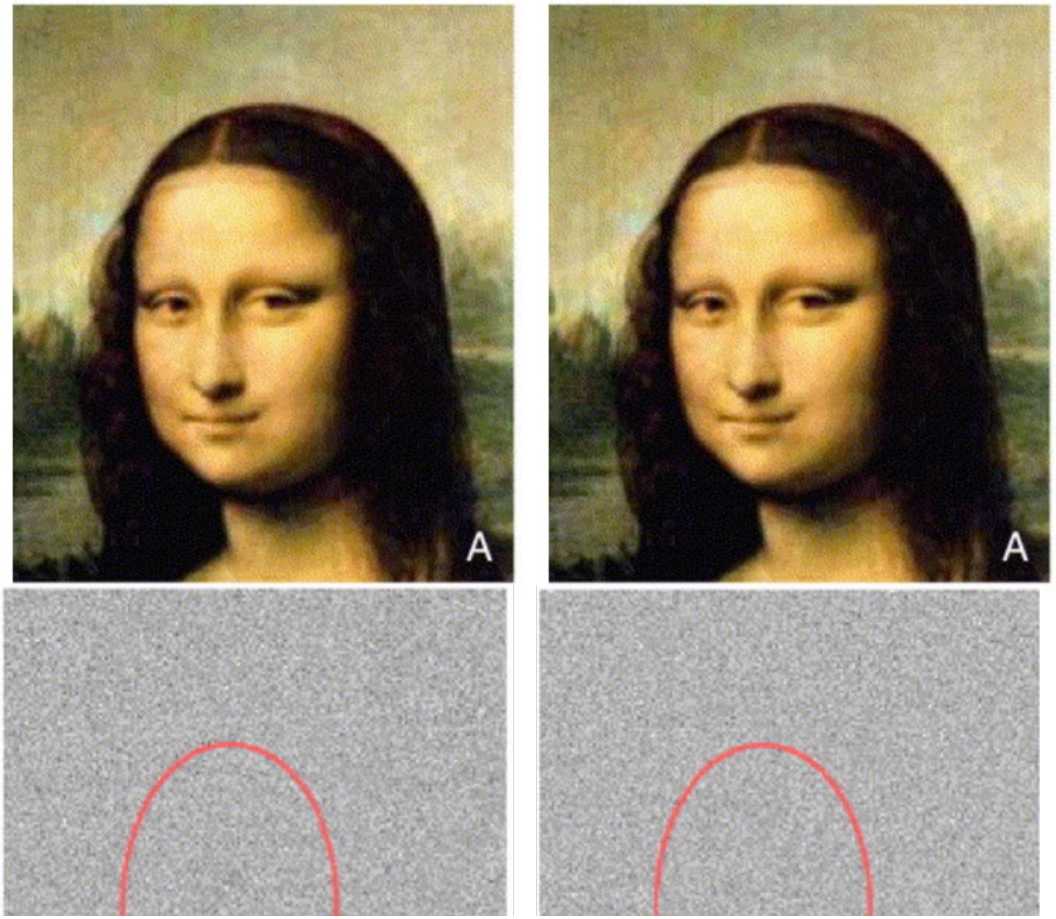

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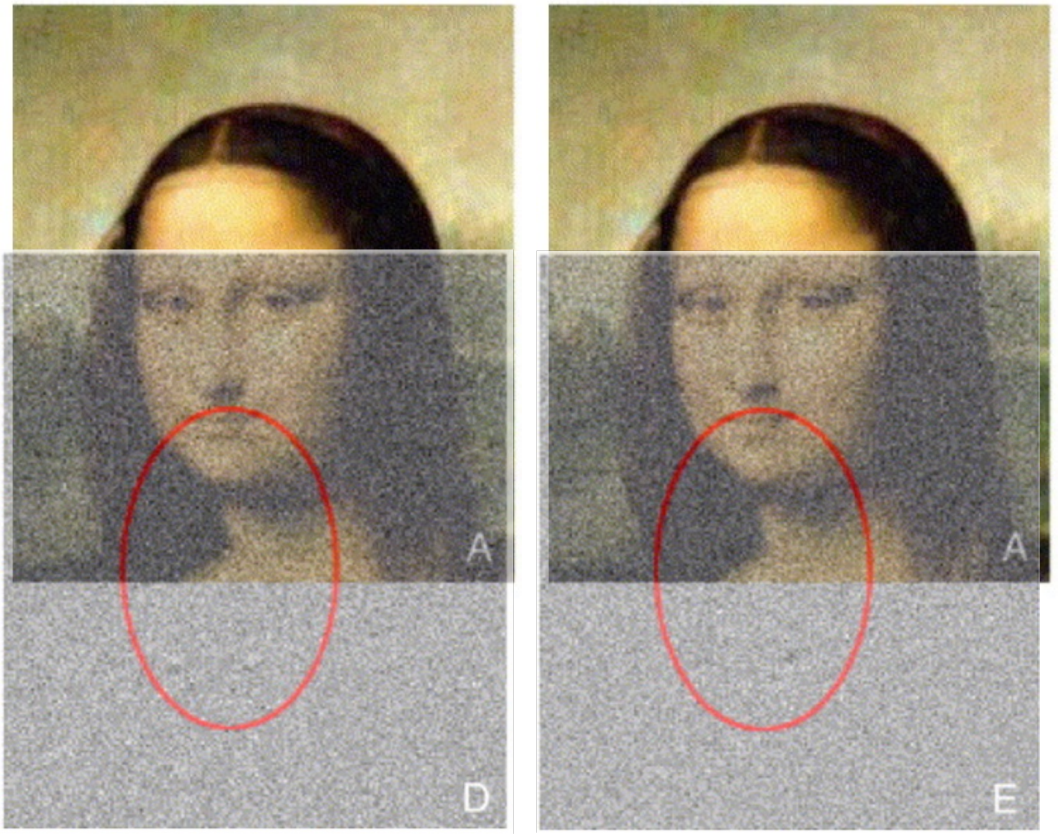

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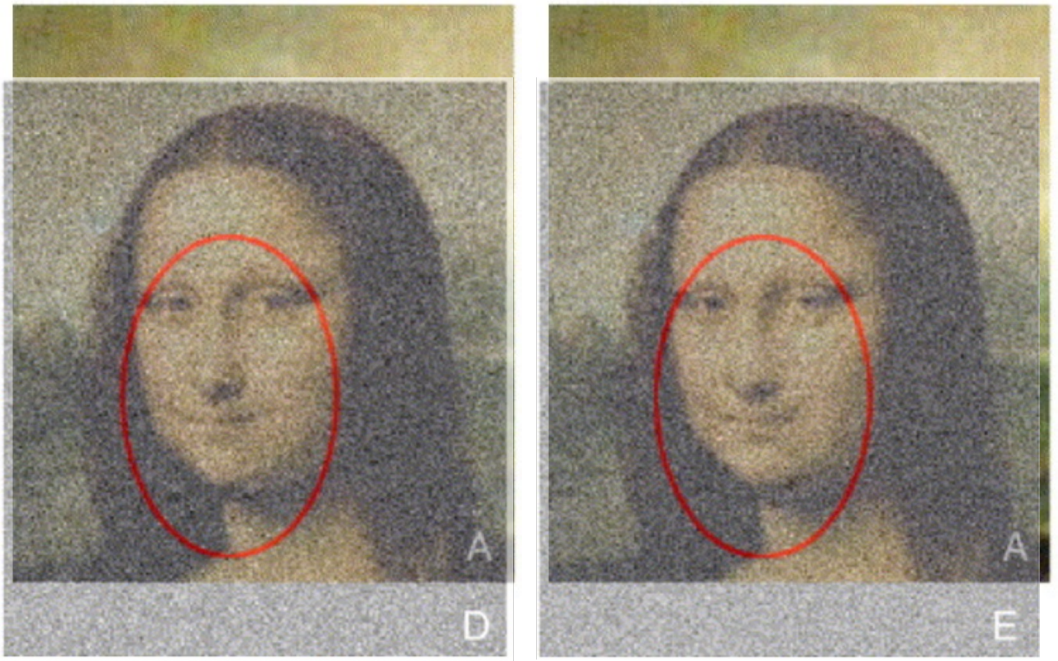

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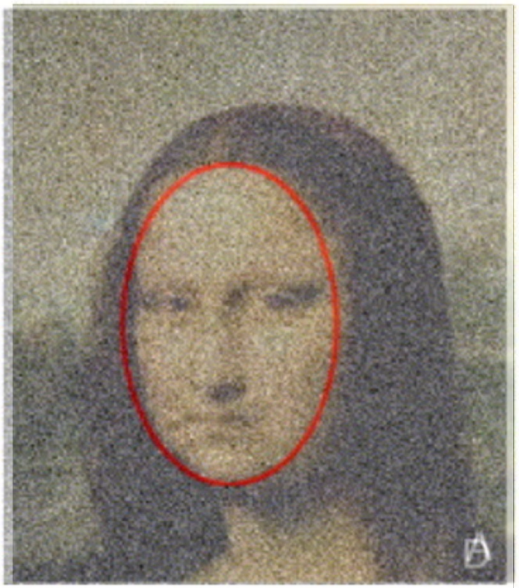

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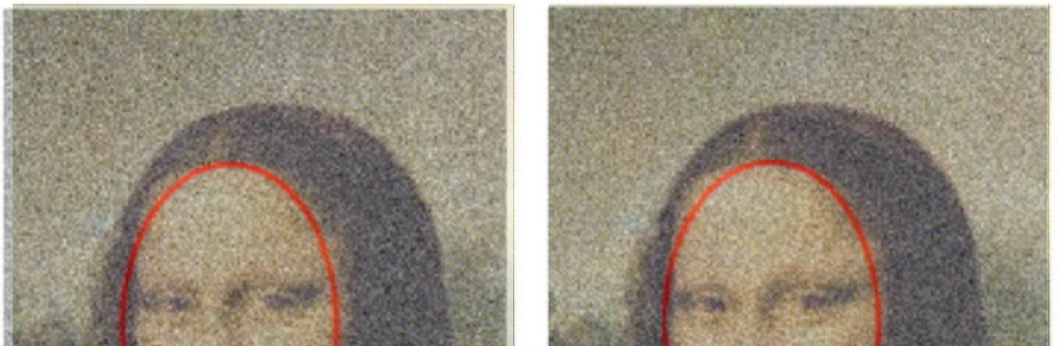

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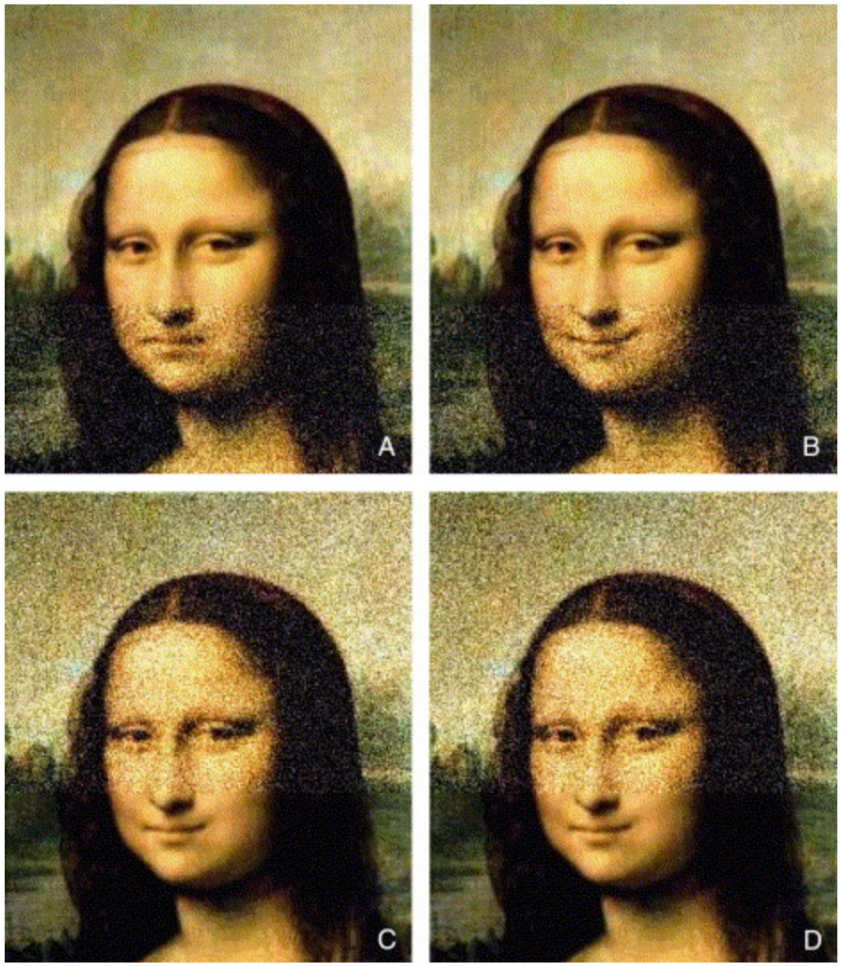
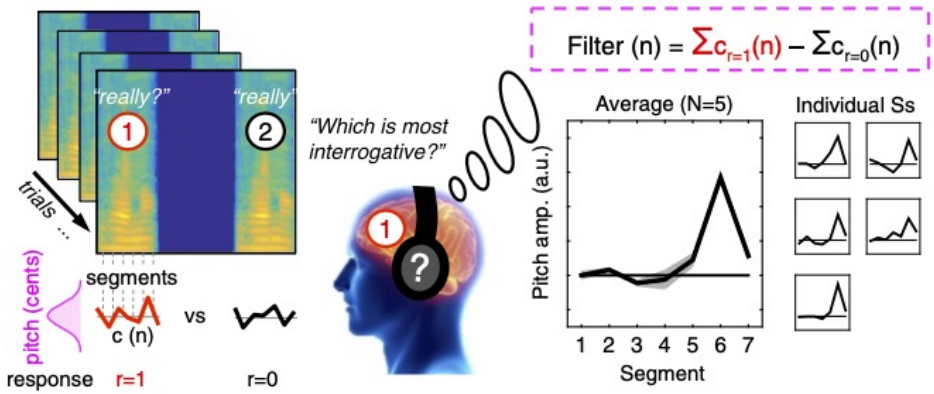


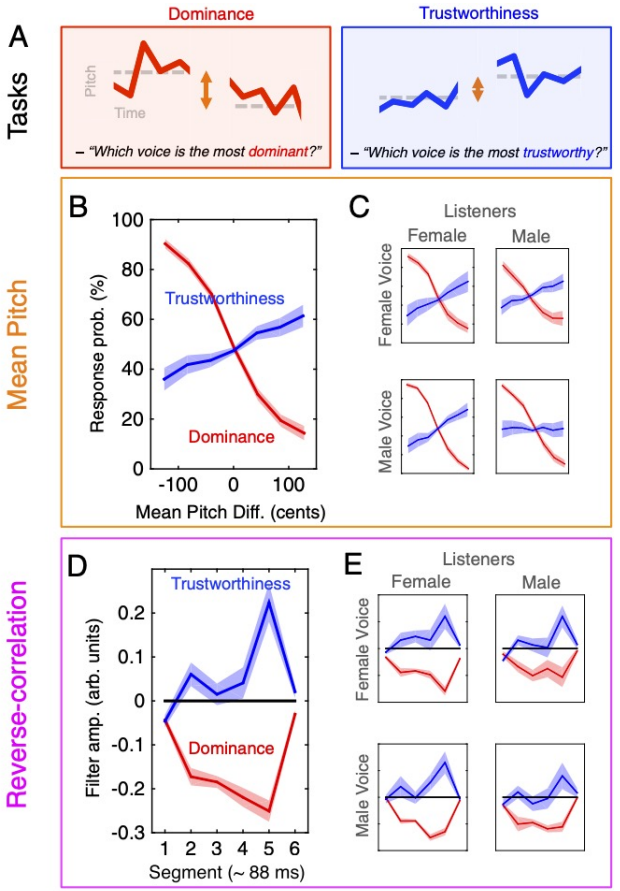
Explaining AI as we probe cognition

Cracking the social code of speech prosody using reverse correlation

Emmanuel Ponsot[a,b,c,1], Juan José Burred[d], Pascal Belin[e,f,g,2], and Jean-Julien Aucouturier[a,h,2]

[a]Sciences et Technologies de la Musique et du Son, UMR 9912, Institut de Recherche et Coordination Acoustique/Musique, CNRS and Sorbonne Université, 75004 Paris, France; [b]Laboratoire des Systèmes Perceptifs, UMR 8248, Ecole Normale Supérieure, Paris Sciences et Lettres Research University, 75005 Paris, France; [c]Département d'Études Cognitives, Ecole Normale Supérieure, Paris Sciences et Lettres Research University, 75005 Paris, France; [d]Independent Researcher, 75013 Paris, France; [e]Institut de Neurosciences de la Timone, UMR 7289, Centre National de la Recherche Scientifique and Aix-Marseille Université, 13007 Marseille, France; [f]Institute of Neuroscience and Psychology, University of Glasgow, Glasgow G12 8QQ, United Kingdom; [g]Département





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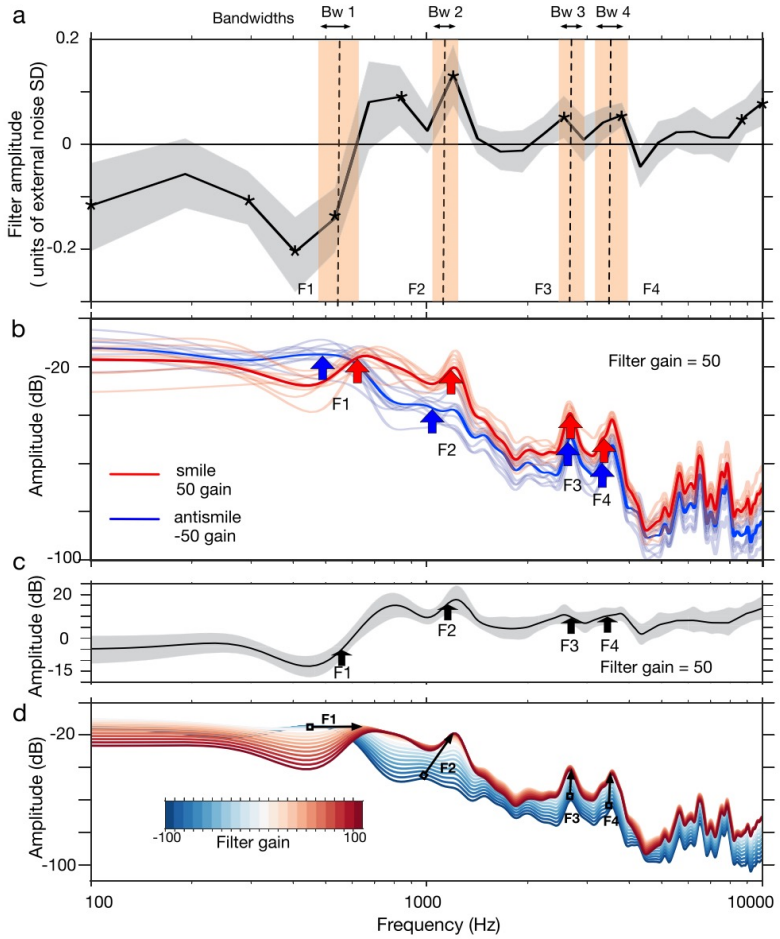
Ponsot *et al.*: JASA Express Letters https://doi.org/10.1121/1.5020989 Published Online 19 January 2018

Uncovering mental representations of smiled speech using reverse correlation

Emmanuel Ponsot,[a)] **Pablo Arias, and Jean-Julien Aucouturier**
STMS (Sciences et Technologies de la Musique et du Son) Lab (Ircam/CNRS/UPMC), 1 place Igor Stravinsky, Paris, France
ponsot@ircam.fr, arias@ircam.fr, aucouturier@ircam.fr



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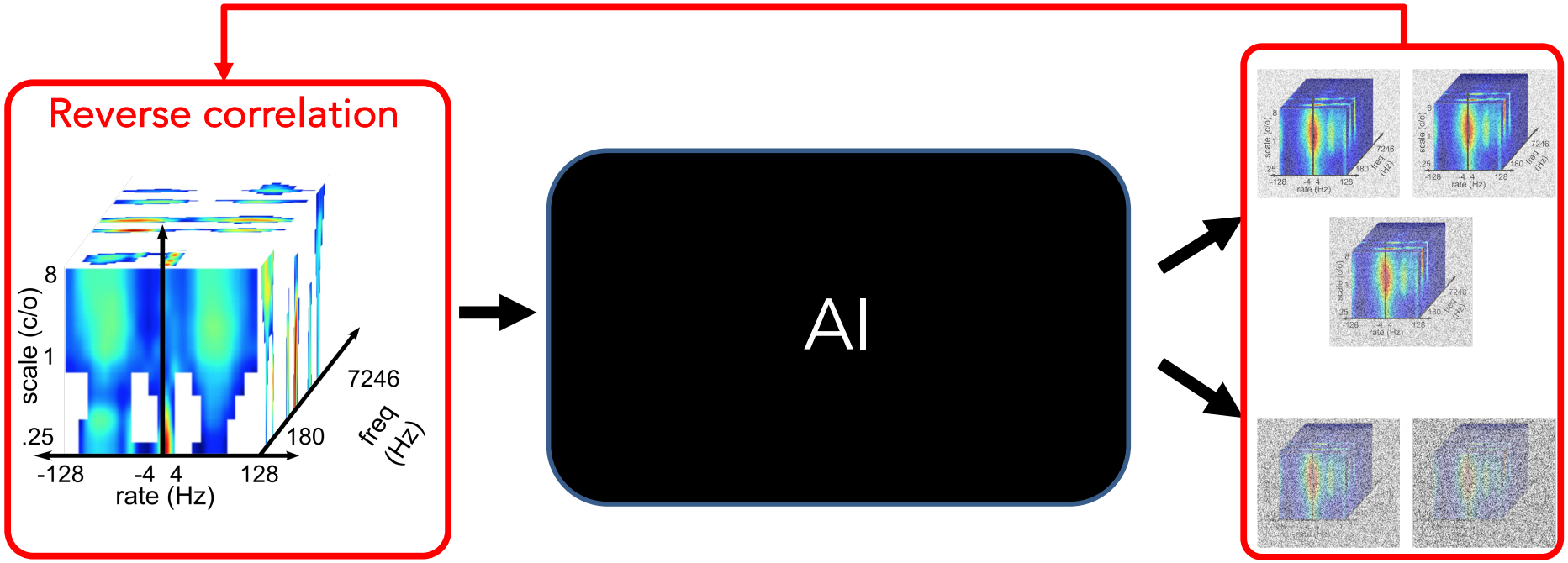
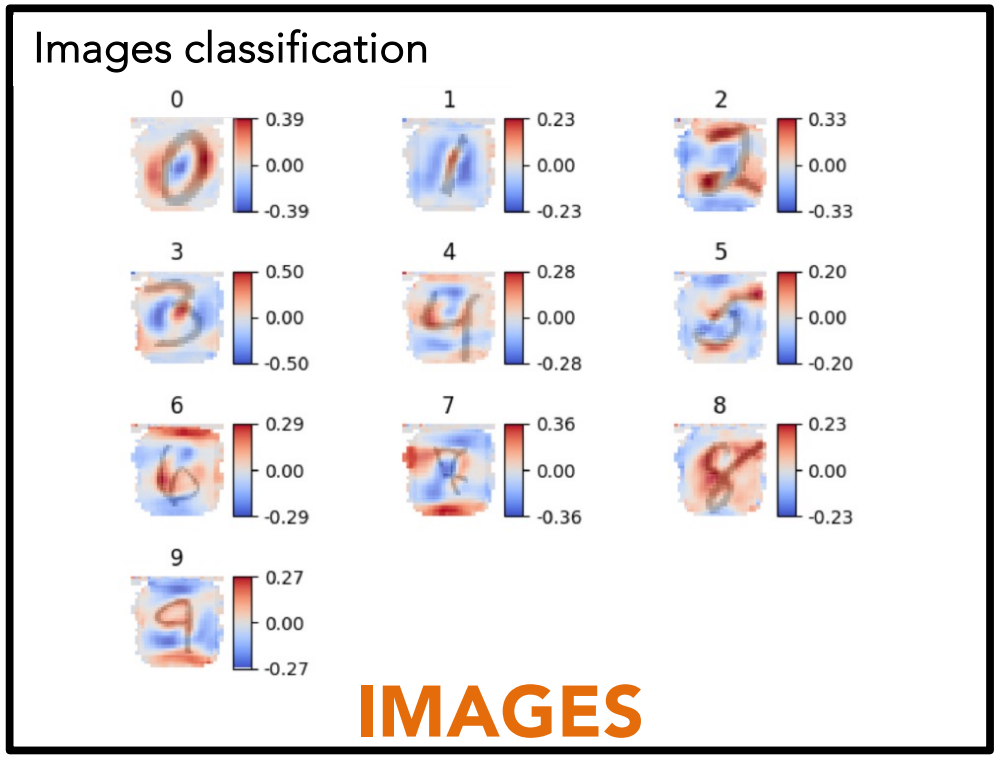


Same idea with classifiers

Thoret, E., Andrillon, T., Leger, D., Pressnitzer, D. (2021)
Probing machine-learning classifiers using noise, bubbles, and reverse correlation
J. Neuro Methods

A versatile approach for AI



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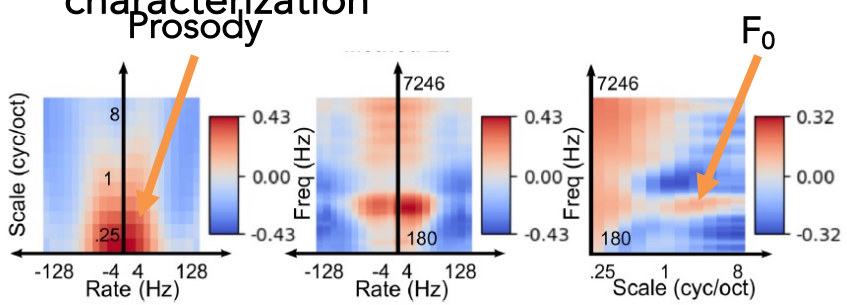
Images classification

speech/music characterization



Speech prototypical STRF

ACOUSTIC REPRESENTATIONS

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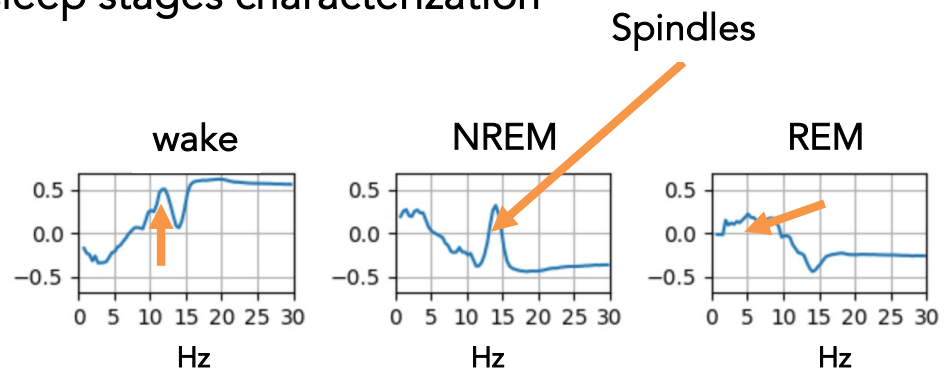

Protoypical EEG
spectrum for each stage

EEG DATA

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Sleep deprivation detected by voice analysis

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NewScientist

Health

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Detecting sleepiness in voice

Lecture à voix haute

→ IA → Sleepy ?

PLOS COMPUTATIONAL BIOLOGY

RESEARCH ARTICLE

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Etienne Thoret[1,2,3]*, Thomas Andrillon[4,5,6], Caroline Gauriau[5,6], Damien Léger[5,6‡], Daniel Pressnitzer[1‡]

1 Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL University, CNRS, Paris, France, **2** Aix-Marseille University, CNRS, Institut de Neurosciences de la Timone (INT) UMR7289, Perception Representation Image Sound Music (PRISM) UMR7061, Laboratoire d'Informatique et Systèmes (LIS) UMR7020, Marseille, France, **3** Institute of Language Communication and the Brain, Aix-Marseille University, Marseille, France, **4** Sorbonne Université, Institut du Cerveau - Paris Brain Institute - ICM, Mov'it team, Inserm, CNRS, Paris, France, **5** Université Paris Cité, VIFASOM, ERC 7330, Vigilance Fatigue Sommeil et santé publique, Paris, France, **6** APHP, Hôtel-Dieu, Centre du Sommeil et de la Vigilance, Paris, France

‡ These authors joint last first authorship on this work.
* etienne.thoret@univ-amu.fr

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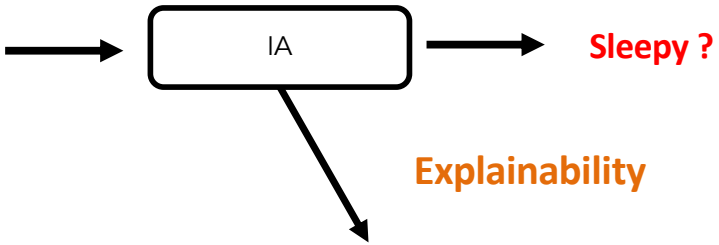

Reverse correlation: « probing AI as we probe brain »

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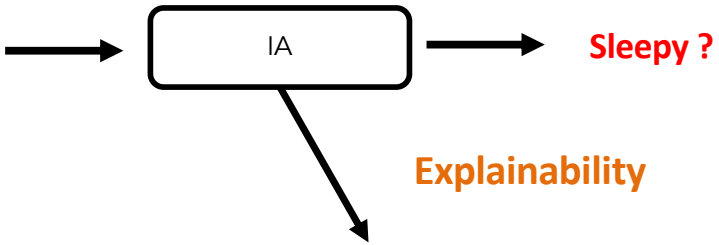

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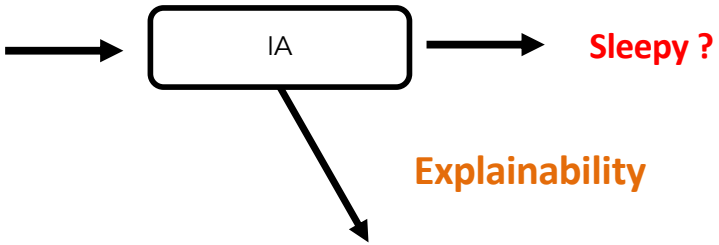

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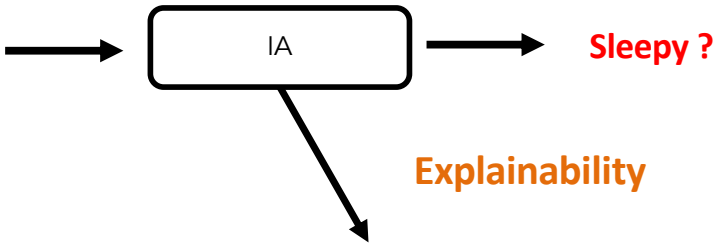

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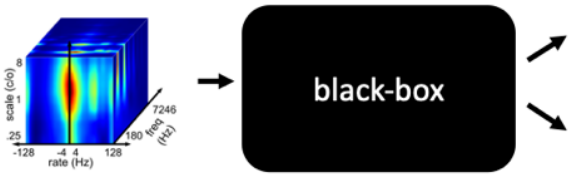

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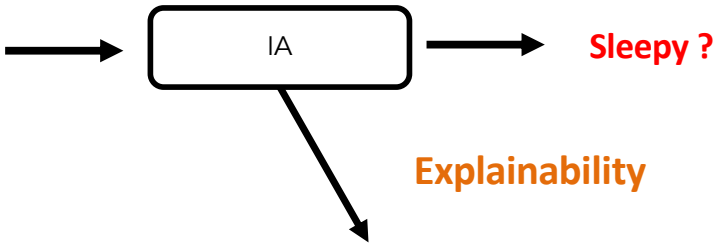

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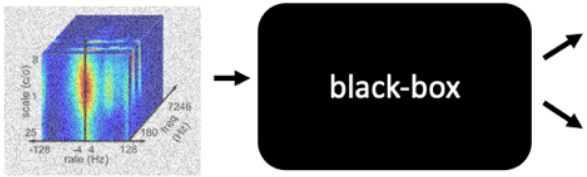

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RESEARCH ARTICLE

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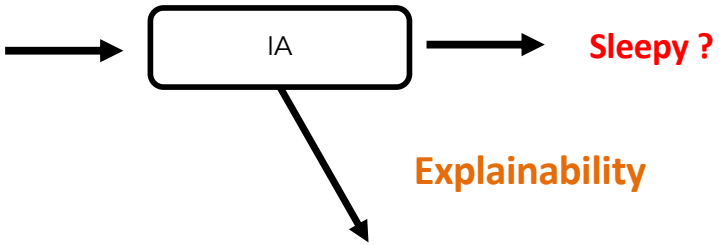

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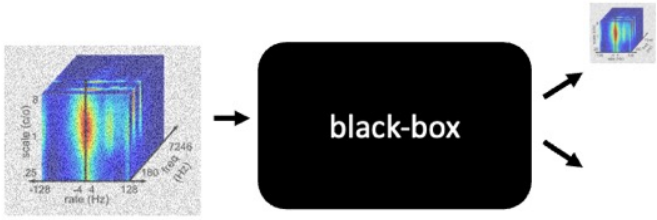

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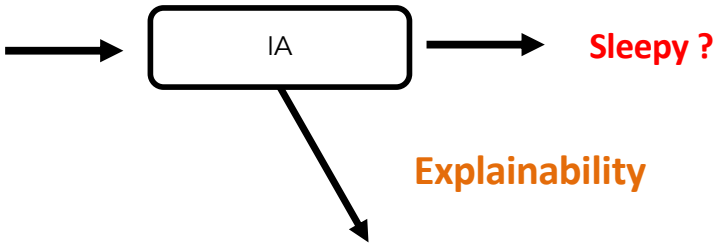

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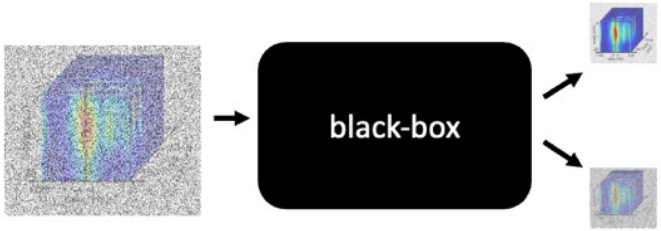

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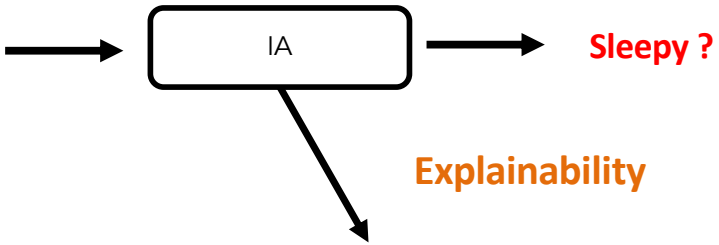

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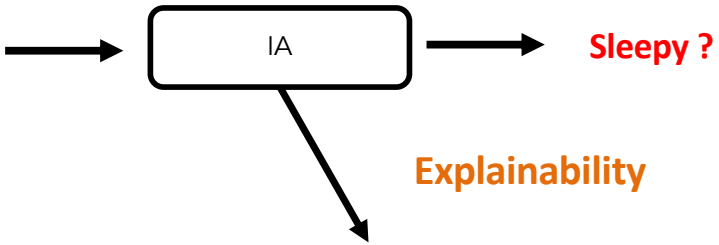

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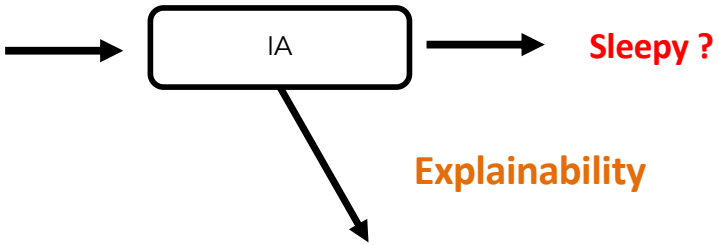

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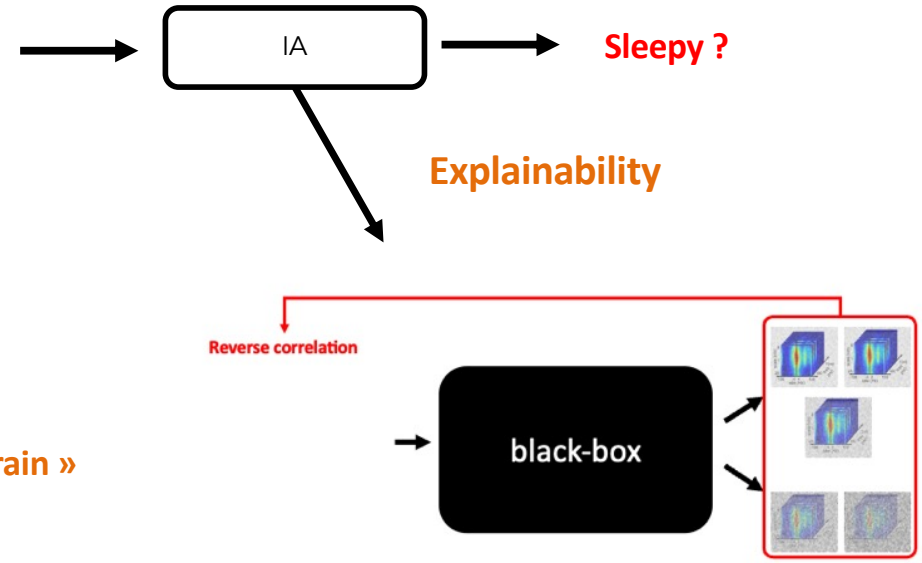

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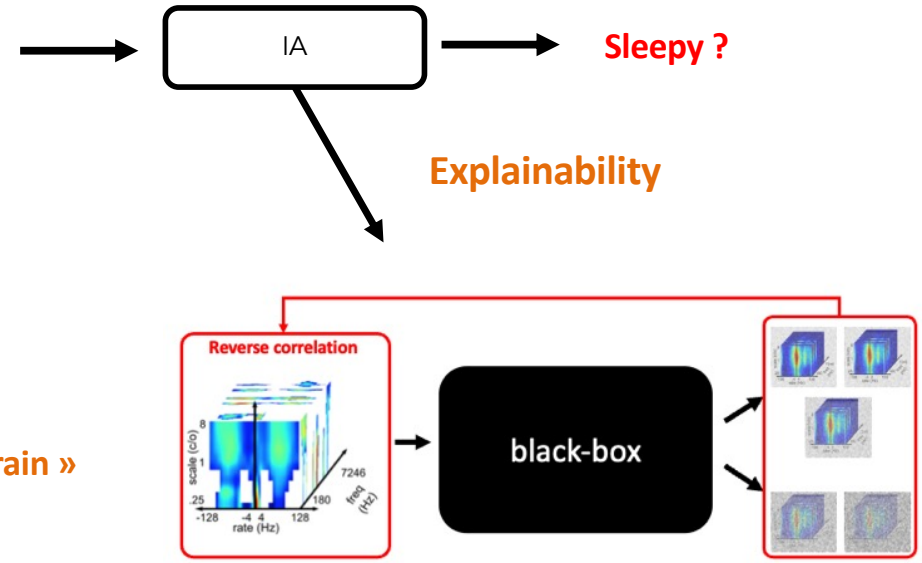

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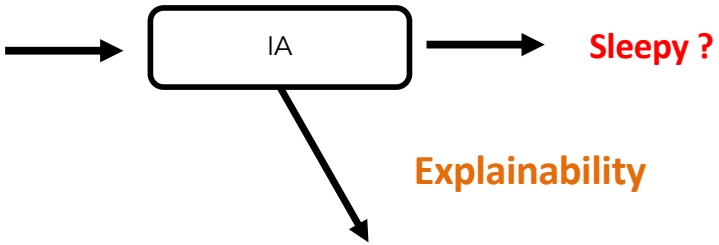

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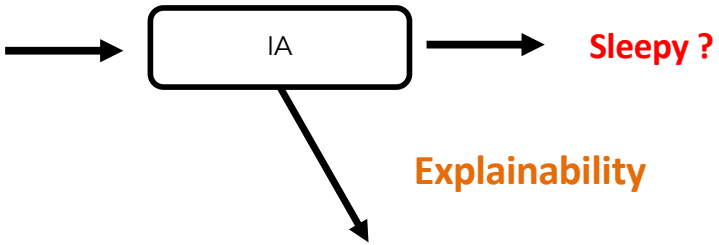
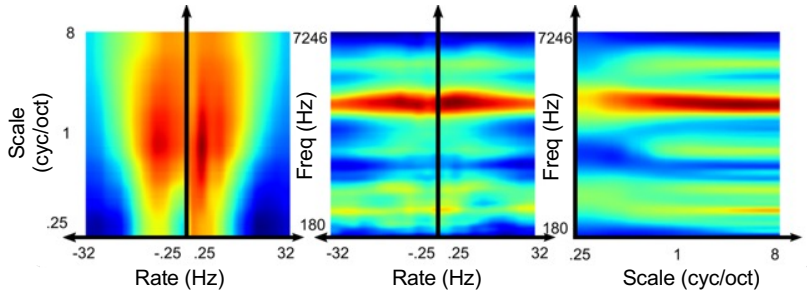


Sleepiness vocal biomarker



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Explaining AI to create vocal biomarkers

How to apply it to DNNs?

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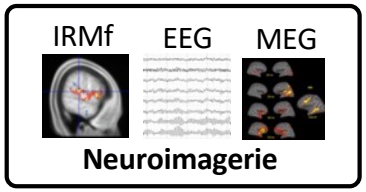
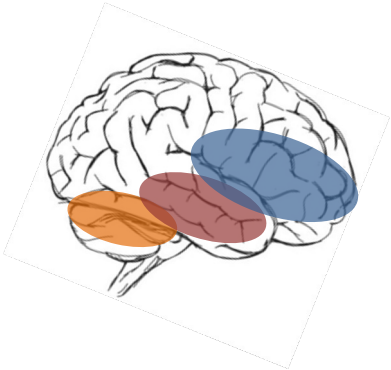
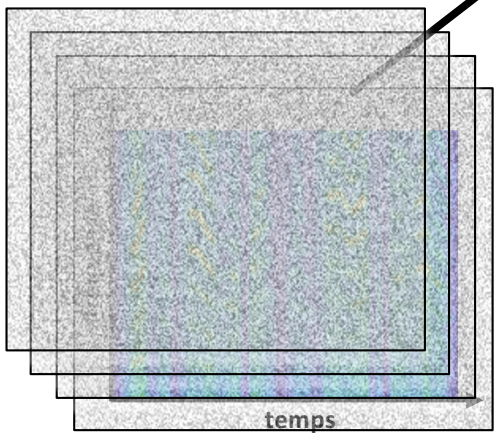
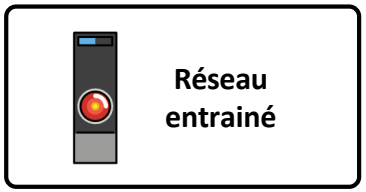
Réseau biologique

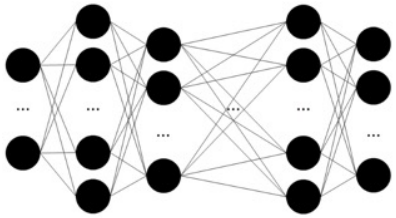






Réseau artificiel





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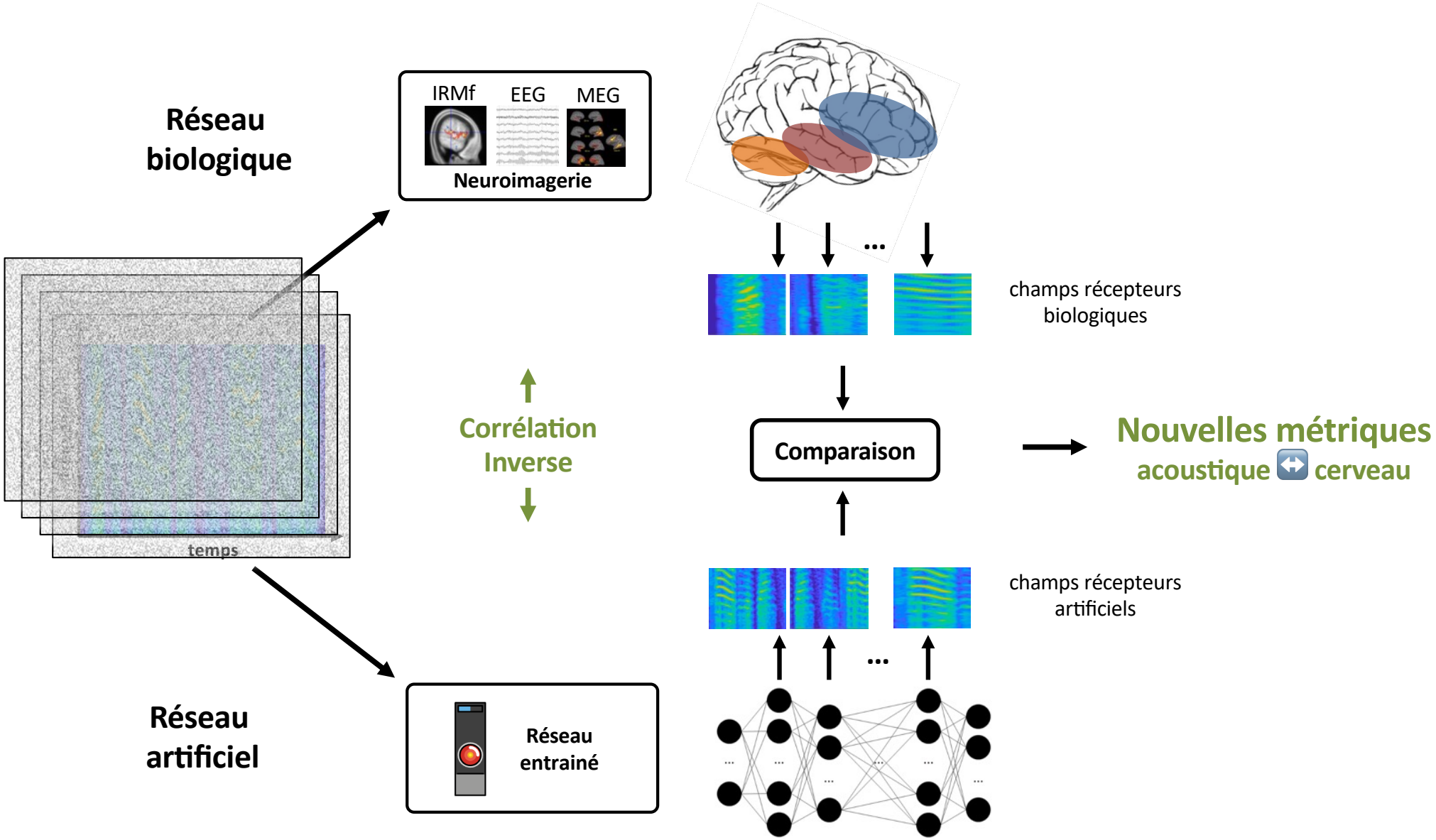
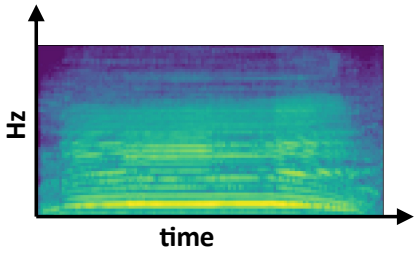


How to apply it to DNNs?

Database

- Making sense of sounds database (CVSSP)
- *Sounds labeled by humans in 5 categories*
- 5 x 300 audio samples of 5 seconds cuted in 2 seconds
- Logmel spectrogram : 64x129 features
- 2250 training samples
- 750 testing samples



5 categories

- Human
- Urban
- Nature
- Music
- Effects

Deepnet architecture

- CNN with 6 convolutional layers
  - Conv2d (9,9), BN, ReLU, BN, MaxPool2D
  - Conv2d (6,6), BN, ReLU, BN, MaxPool2D
  - Conv2d (6,6), BN, ReLU, BN, MaxPool2D
  - Conv2d (6,6), BN, ReLU, BN, MaxPool2D
  - Conv2d (6,6), BN, ReLU, BN, MaxPool2D
  - Conv2d (3,3), BN, ReLU, BN, MaxPool2D
  - GlobalMaxPool2D

Training performances:

- 100 epochs
- Training accuracy: .97
- Testing accuracy: .75

Interpretability of the global CNN and of the layers

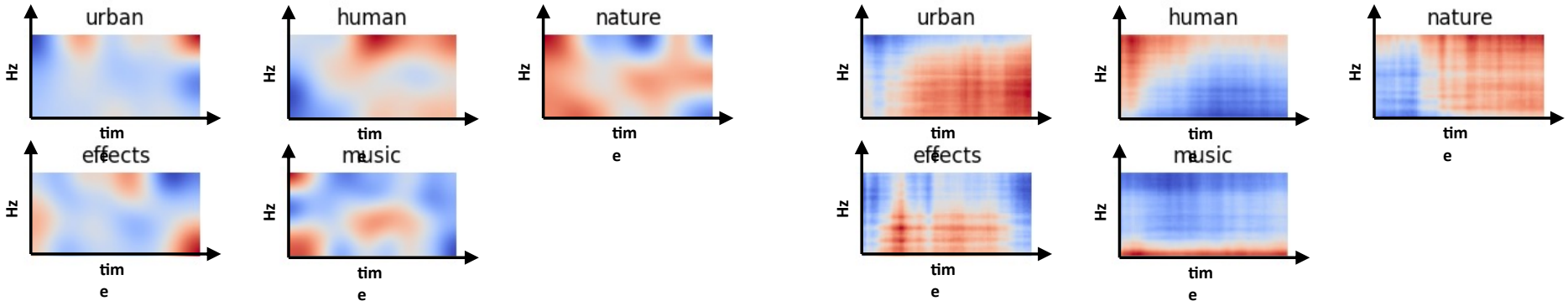
- one classifier at the output of each layers
- Bubbles method
- Reverse correlation

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

Layer #1



Potent information

Represented information

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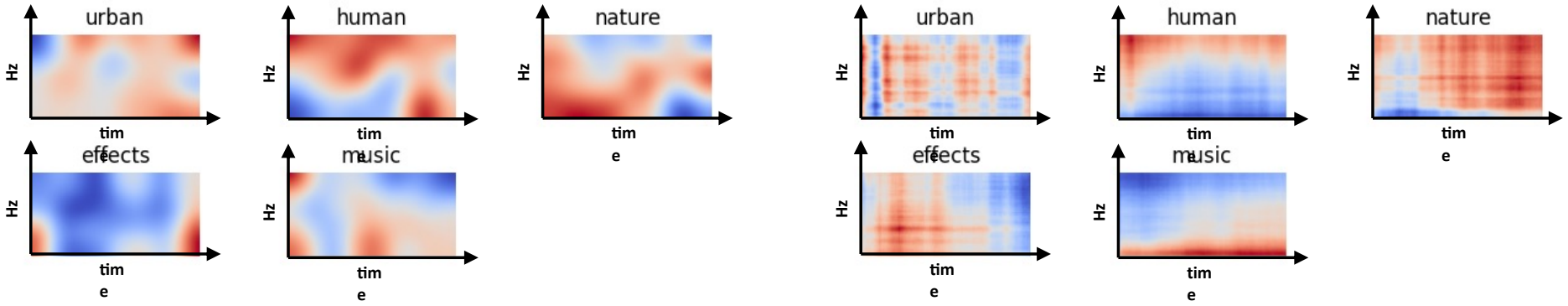
Layer #2



Potent information

Represented information

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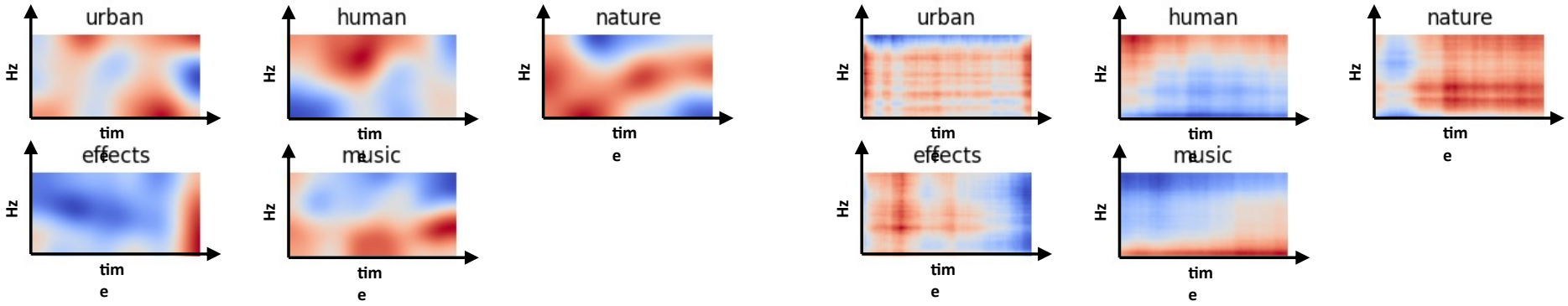
- The prototypical encoded information

Layer #3



Potent information

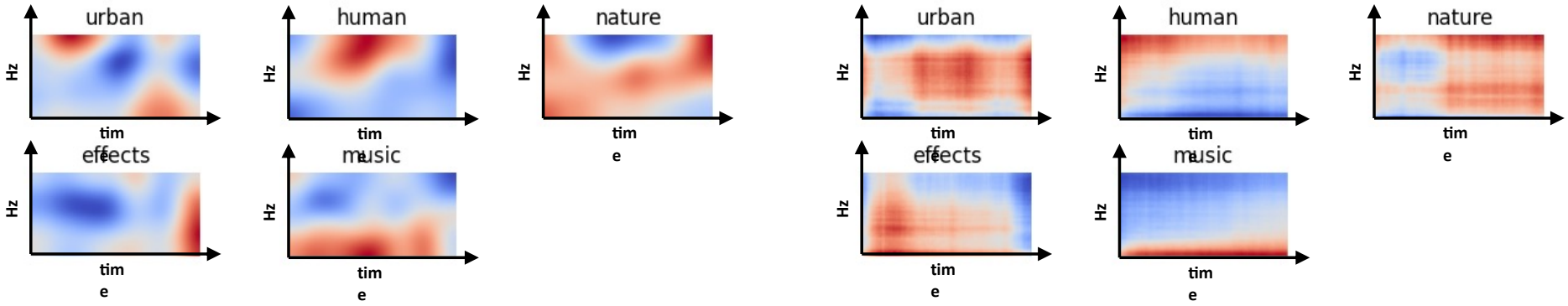
Represented information

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

Layer #4



Potent information

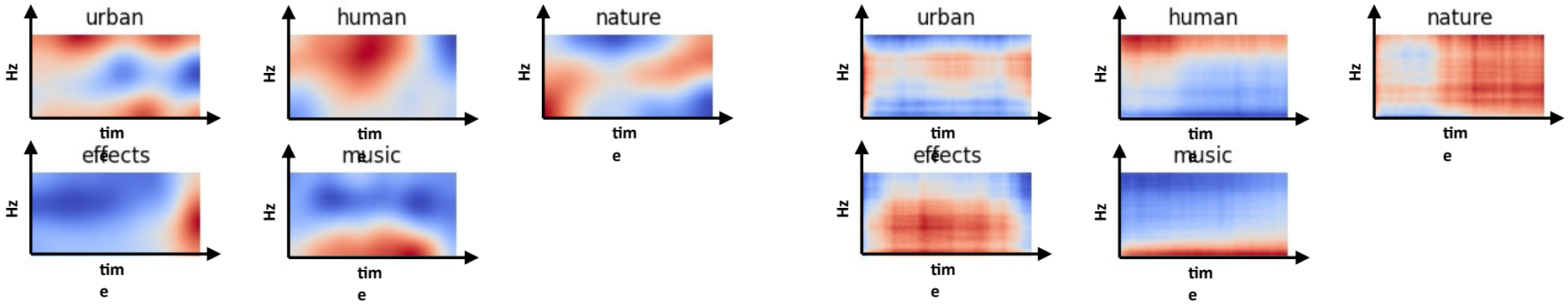
Represented information

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

Layer #5



Potent information

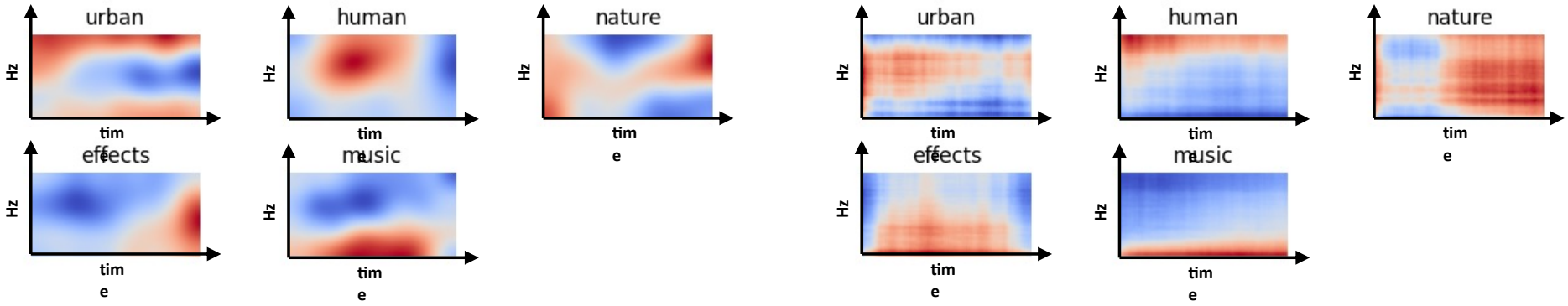
Represented information

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

Layer #6



Potent information

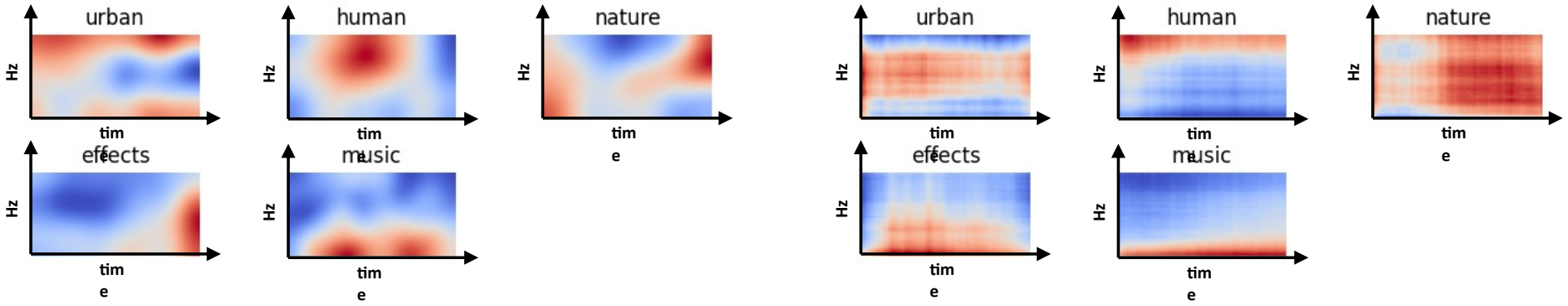
Represented information

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

Globally



Potent information

Represented information

Does it make sense?

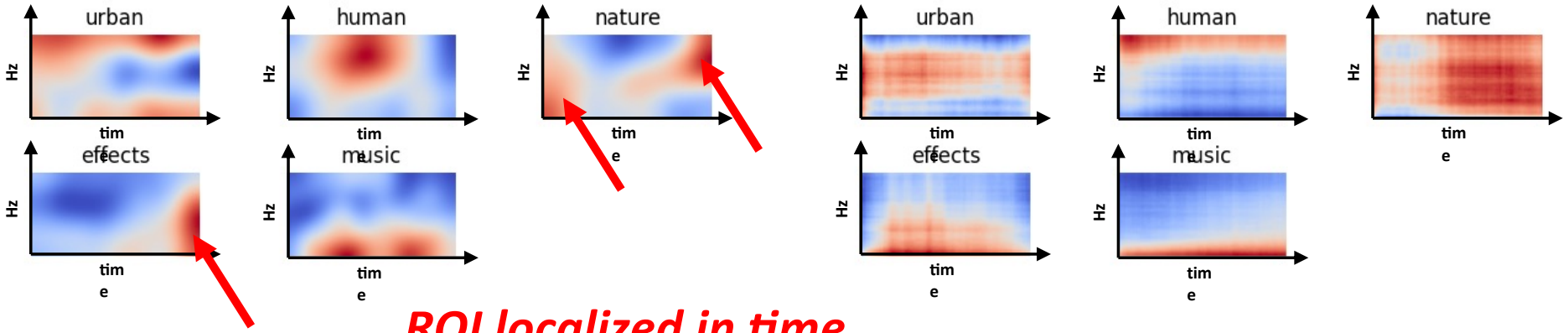
acoustic vs. perception

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

Globally



ROI localized in time, plausible?

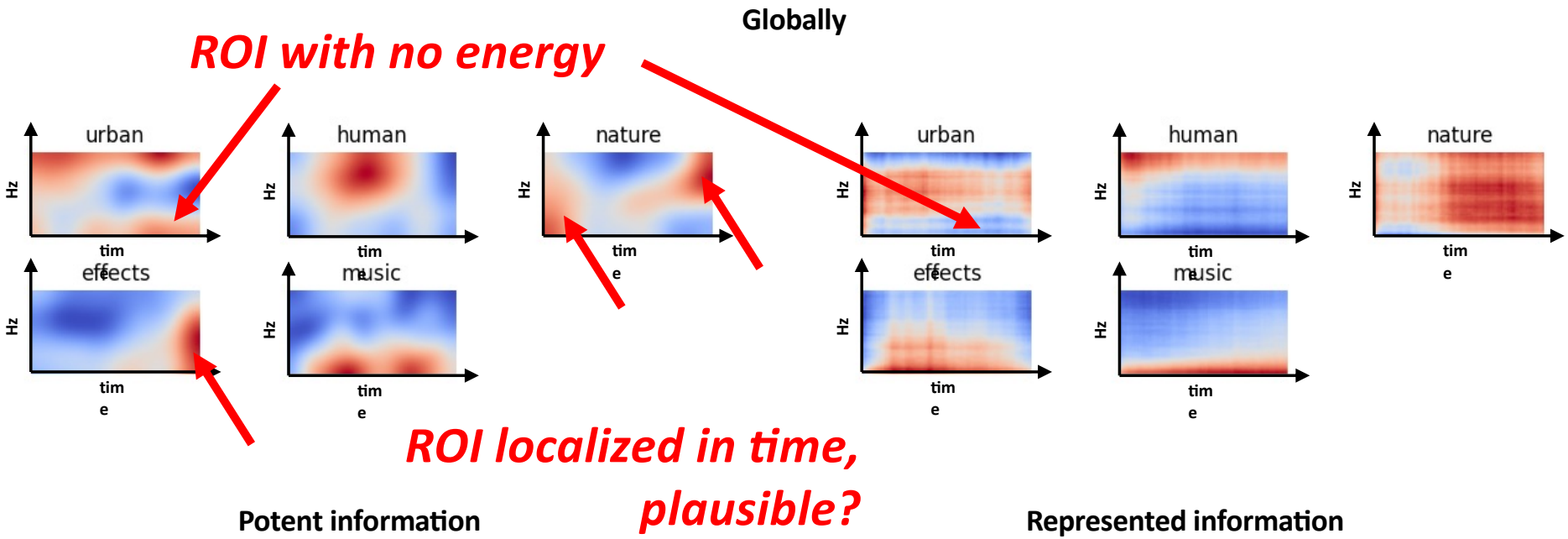
Potent information **Represented information**

Does it make sense? ***acoustic vs. perception***

How to apply it to DNNs?

For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information



Does it make sense?

acoustic vs. perception

How to apply it to DNNs?

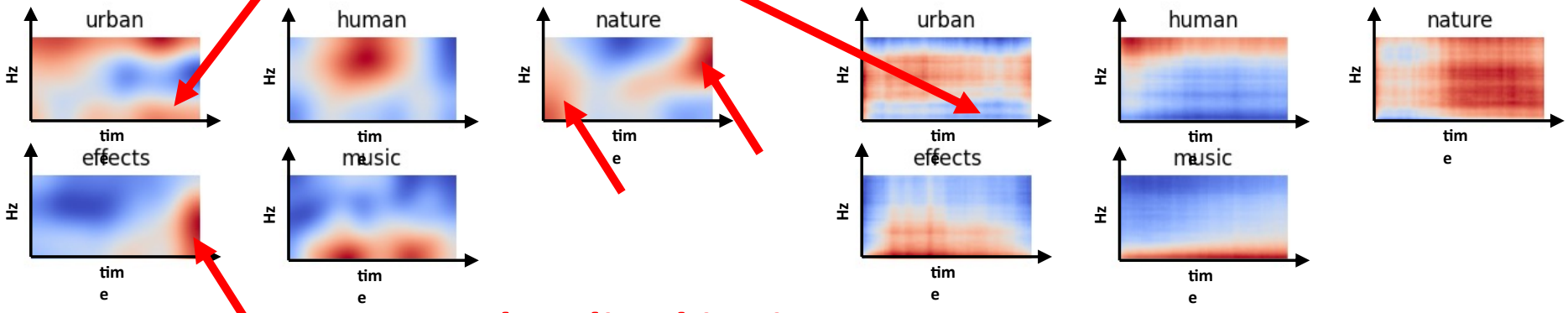
For each layer, we interpret:

- The most relevant areas
- The prototypical encoded information

CNN optimizes the discrimination for separability, not for perception

ROI with no energy

Globally



ROI localized in time, plausible?

Potent information

Represented information

Does it make sense?

acoustic vs. perception

Hands on!!

https://github.com/EtienneTho/neuroschool-phd-program-xAI-2024

1. **Training a classifier**

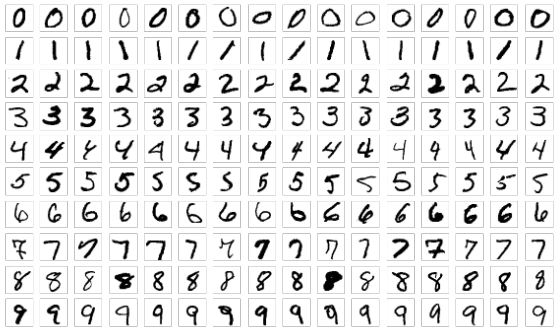
2. **Random perturbations:** additive or multiplicative

3. **Bubbles**

4. **Reverse correlation**

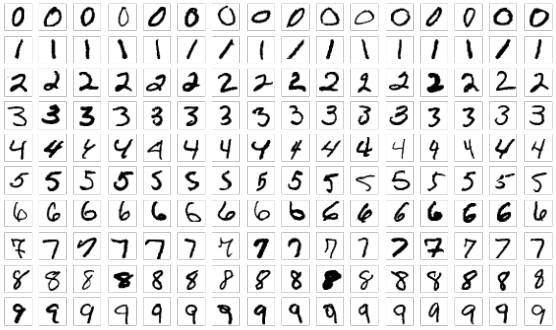
Hands on!!

Pseudo random noise



Hands on!!

Pseudo random noise



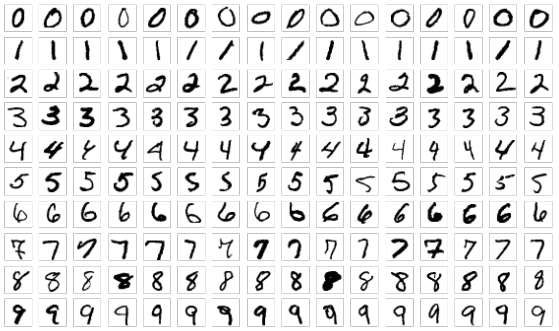
PCA

Latent space

$X_{1,1}$
$X_{2,1}$
$X_{3,1}$
.
.
.
$X_{N,1}$

Hands on!!

Pseudo random noise



PCA

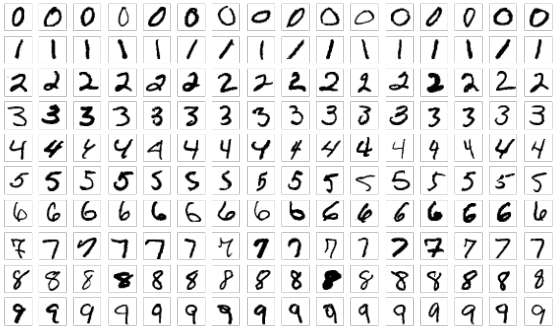
Latent space

$X_{1,1}$
$X_{2,1}$
$X_{3,1}$
.
.
.
$X_{N,1}$

Noise

Hands on!!

Pseudo random noise



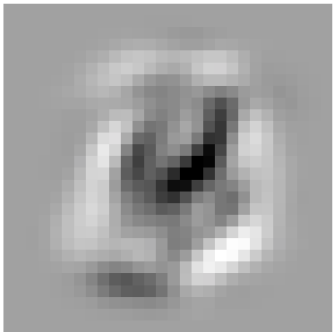
PCA →

Latent space

$X_{1,1}$
$X_{2,1}$
$X_{3,1}$
.
.
.
$X_{N,1}$

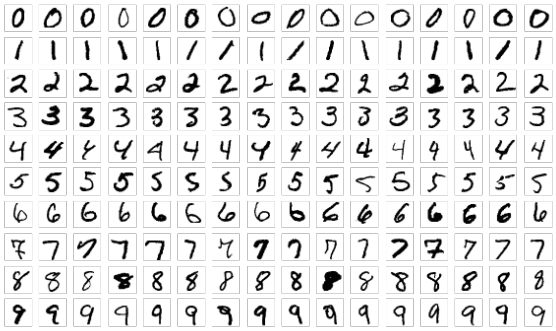
Noise

PCA^{-1} →



Hands on!!

Pseudo random noise



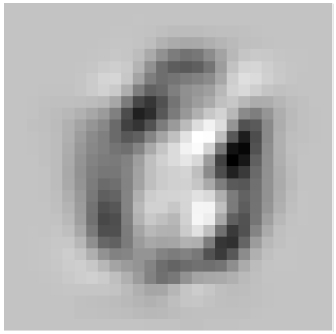
PCA →

Latent space

$X_{1,2}$
$X_{2,2}$
$X_{3,2}$
.
.
.
$X_{N,2}$

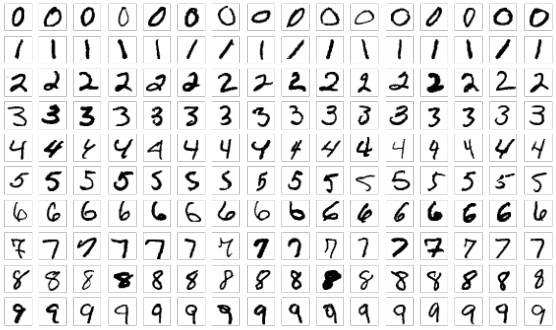
Noise

PCA^{-1} →



Hands on!!

Pseudo random noise



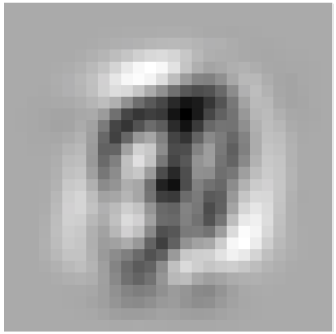
PCA →

Latent space

$X_{1,3}$
$X_{2,3}$
$X_{3,3}$
.
.
.
$X_{N,3}$

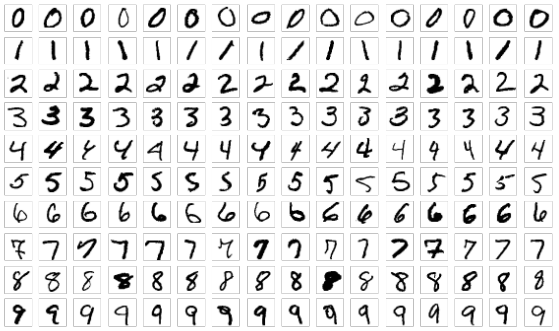
Noise

PCA^{-1} →



Hands on!!

Pseudo random noise



PCA →

Latent space

$X_{1,4}$
$X_{2,4}$
$X_{3,4}$
.
.
.
$X_{N,4}$

Noise

PCA^{-1} →