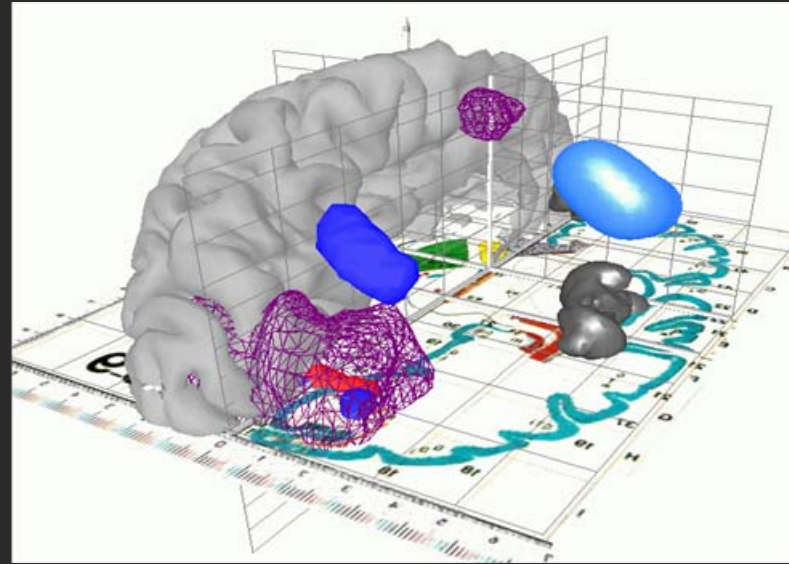# Cogito componentiter
– ergo sum

"I think in components – therefore I am"

Outline

- **Cognitive component analysis:**
  - A definition
  - A motivation for independent components

- **Machine learning tools (ICA, sparse representations)**

- **Example: Phonemes as cognitive components**
- **Example: Communities as cognitive comp. of networks**

- **Conclusion and outlook**

Cognitive Component Analysis

ENCYCLOPÆDIA BRITANNICA > online

- ■ What is cognition?
  - – "The act or process of knowing - Cognition includes every mental process that may be described as an experience of knowing (including perceiving, recognizing, conceiving and reasoning) as distinguished from an experience of feeling and willing."

    -Brittanica Online (2005)
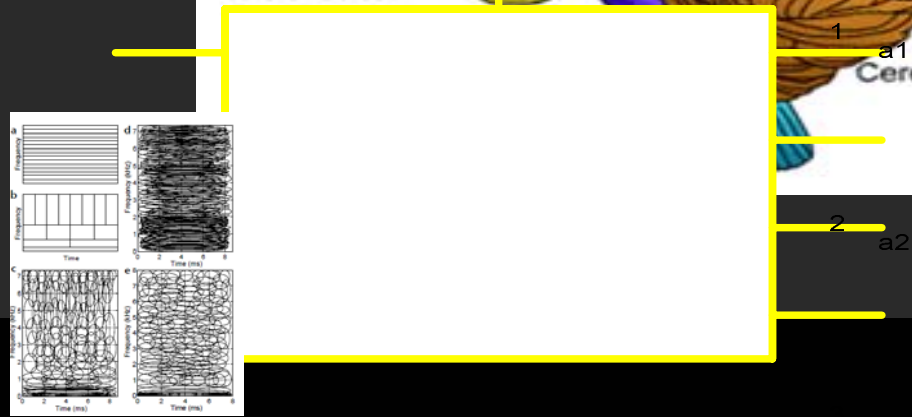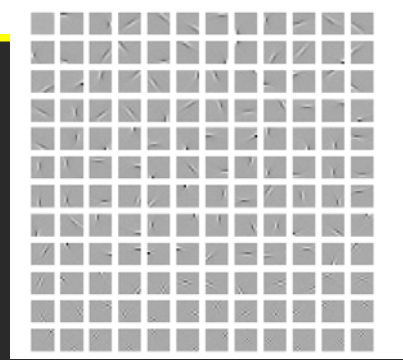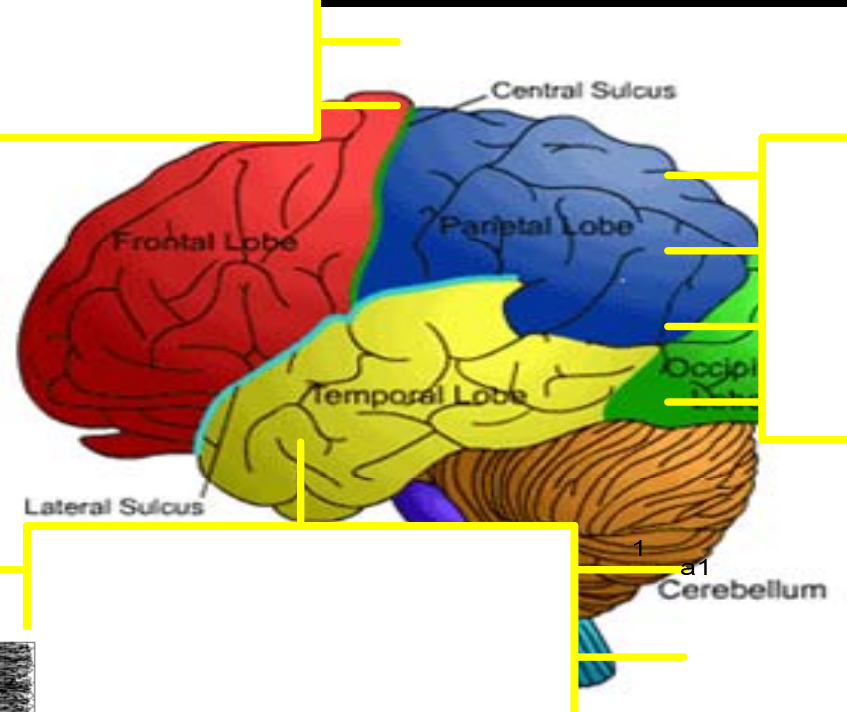
- ■ Cognitive component analysis (COCA)
  - – The process of unsupervised grouping of data so that the ensuing group structure is well-aligned with that resulting from human cognitive activity:

    "**Cognitive compatibility"**

DTU

Ecological modeling

Central Sulcus

Frontal Lobe

Parietal Lobe

Temporal Lobe

Occipi...

Lateral Sulcus

Cerebellum

1

a1

2

a2

Abstract data

Cognitive Component Analysis: Why independence?

- Cognitive component analysis (COCA)
  - The process of unsupervised grouping of data so that the ensuing group structure is well-aligned with that resulting from human cognitive activity

- The **object** is a basic notion in cognitive psychology;
  - E.g. modeling number of objects in short time memory.
  - A pragmatic definition of **an object** is "**a signal source that maintains a minimum of independent behavior in a given environment**".
  - Thus, independent component analysis could attain a key role in understanding cognition (Hansen et al., 2005)

- Theoretical issues: we are interested in the relation between supervised and un-supervised learning. **How compatible are the hidden representations of supervised and unsupervised models?** Related to the discussion of the utility of unlabeled examples in supervised learning.

Cognitive compatibility

Unsupervised Learning

$$p(\mathbf{x} \mid \mathbf{w}_u)$$

Supervised learning

$$p(\mathbf{y} \mid \mathbf{x}, \mathbf{w}_s)$$

When can COCA be expected to work?

- If the "structure" in the relevant feature space is well aligned with the label structure we expect high **cognitive compatibility**

- Benign case,

    malign case,

        worst case….

Vector space representation

- Abstract representation - can be used for all digital media
- A "cognitive event" is represented as a point in a high-dimensional "feature space" – document similarity ~ spatial proximity in a given metric

- Text: Term/keyword histogram, N-grams
- Image: Color histogram, texture measures
- Video: Object coordinates (tracking), active appearance models
- Sound: Spectral coefficients, cepstral coefficients, gamma tone filters

Contexts can be identified by their feature associations (= Latent semantics)

Deerwester, S., Dumais, S. T., Furnas, G. W., Landauer, T. K., & Harshman, R:
Indexing by latent semantic analysis.
Journal of the American Society for Information Science, 41(6), 391-407, (1990)

J. Larsen, L. K. Hansen, T. Kolenda, F. Å. Nielsen: *Independent Component Analysis in Multimedia Modeling*,
Proc. of ICA2003, Nara Japan, 687-696, (2003)

L. K. Hansen, P. Ahrendt, J. Larsen: *Towards Cognitive Component Analysis*. In Proc. of AKRR'05 -International and Interdisciplinary Conference on Adaptive Knowledge Representation and Reasoning, Helsinki (2005)

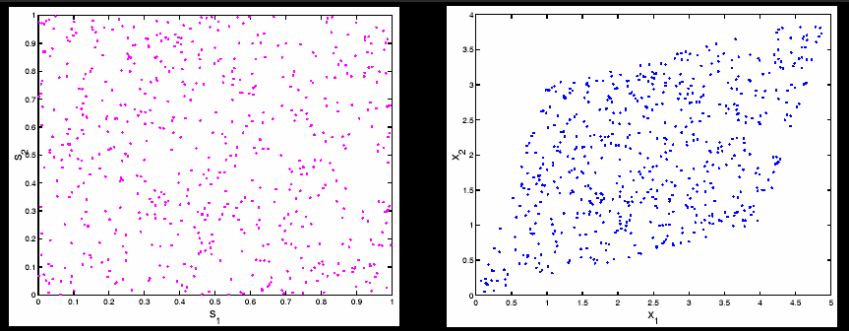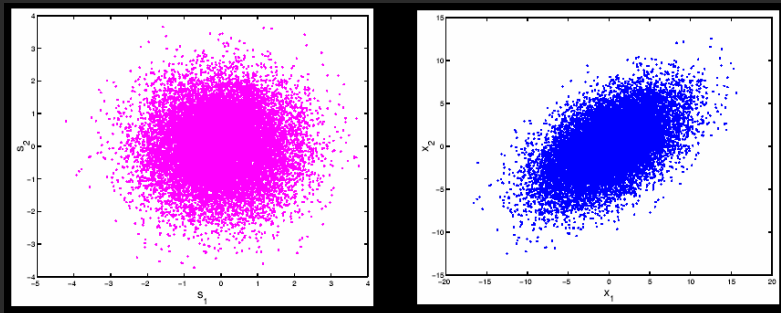# Linear mixing generative model - "Synthesis"

Cognitive event matrix

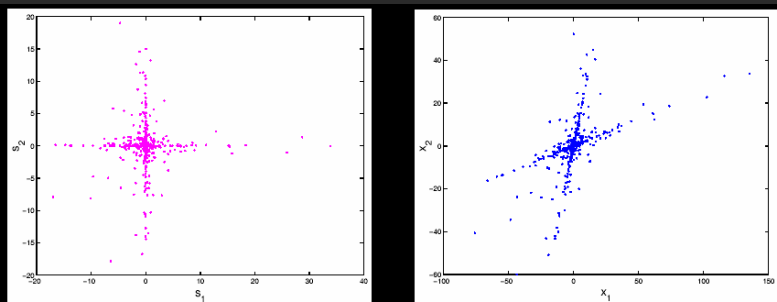Context histograms

Context expressions

Normal sources

$$x(feature, time) = \sum_k A(feature, k) \; s(k, time)$$
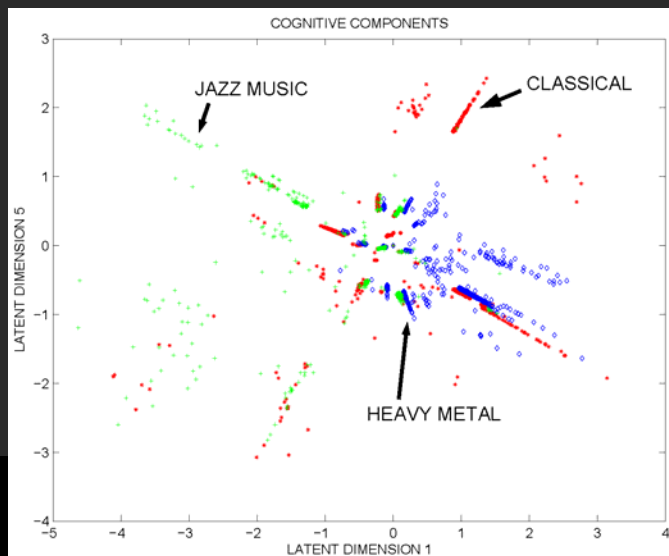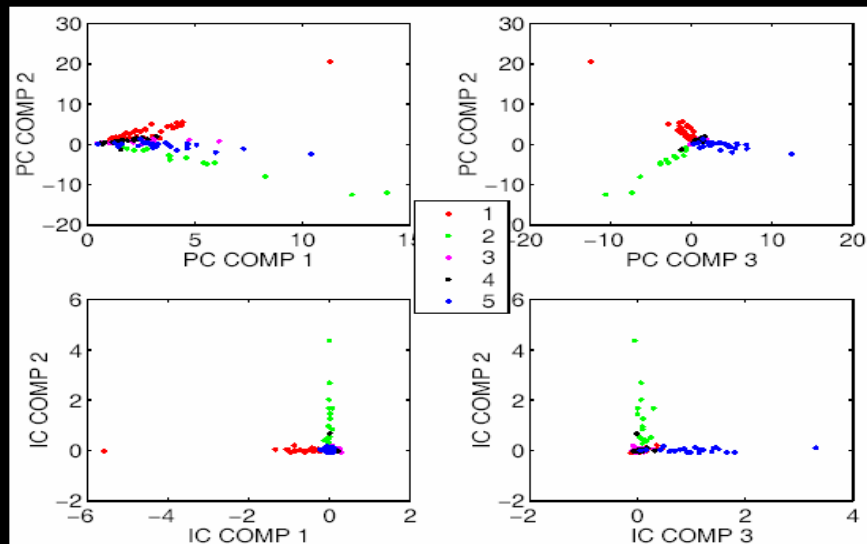

Dense sources

Sparse sources

Linear mixture of
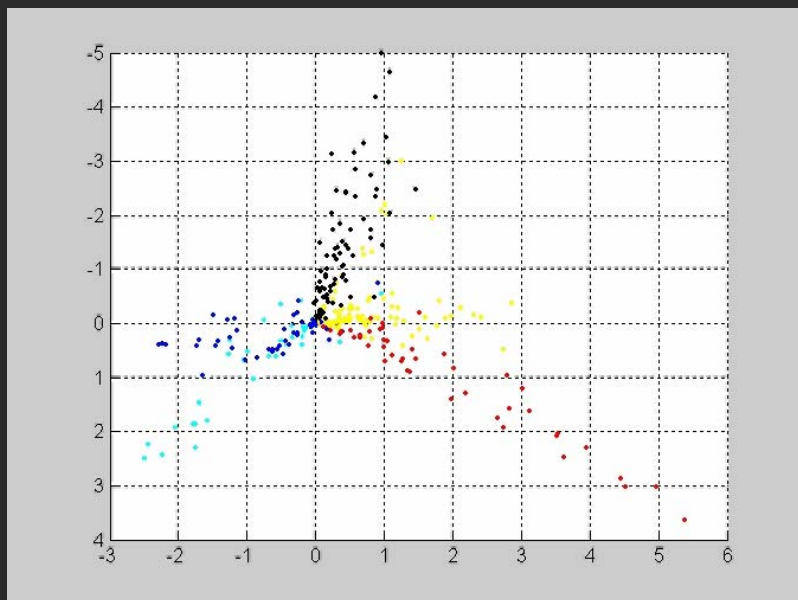independent agents
in term-document
scatterplots

Linear mixture of independent contexts
observed in short time features (mel-
ceptrum) in a music database.

Social networks:
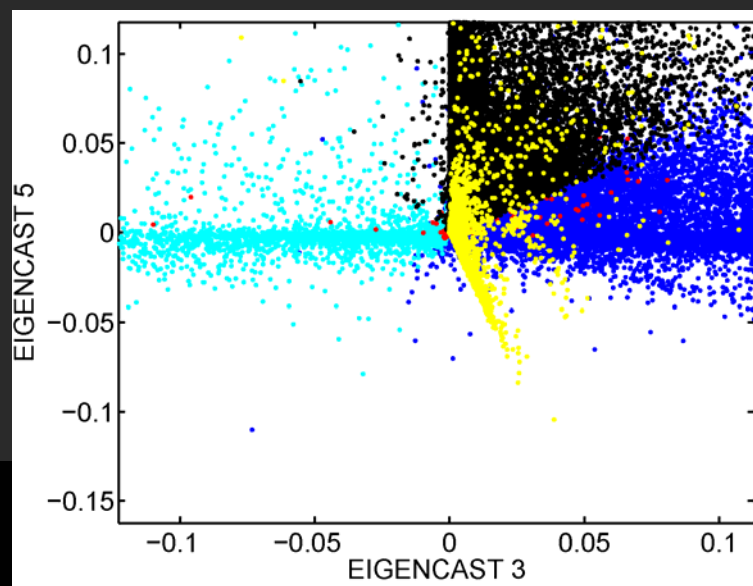## Linear mixtures of independent communities?

"Movie actor network"
- A collaborative small world
network 128.000 movies
380.000 actors

Genre patterns in expert's opinion on
music artists

(AMG400, Courtesy D. Ellis)

Cognitive compatibility: A protocol

■ Train generative models

$$p(x, y) = \sum_{k=1}^{K} p(x, y \mid k) p(k)$$

$$p(x) = \sum_{l=1}^{L} p(x \mid l) p(l) \leftrightarrow p(y \mid l)$$

■ Compare hidden representations:
p(y|l) versus p(y|k), error rates, bit-rates
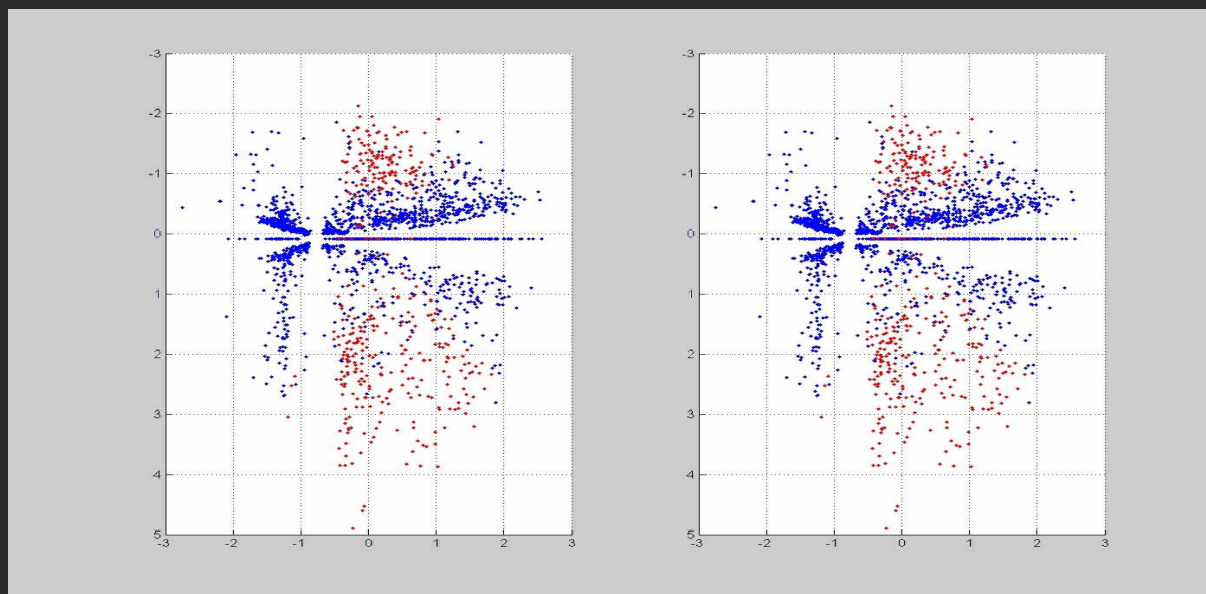
Phoneme classification

Nasal vs oral: "Esprit project ROARS" (Alinat et al., 1993)

Supervised   Unsupervised

Binary classification   Error rates: **0.23** (sup.), **0.22** (unsup.)
Bitrates: **0.48** (sup.), **0.39** (unsup.)

Conclusion & outlook

- ■ Definitions of
  - – cognitive component analysis,
  - – cognitive compatibility

- ■ Protocol for measuring cognitive compatibility

- ■ Outlook: The independent component hypotesis:
  - – Does the brain use old tricks from perception to solve complex "modern" problems?.

Acknowledgments

- Danish Research Councils
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Center for Computational Cognitive Modeling

– bridging computational cognitive psychology and information engineering

$\Sigma\Psi$

Looking for new "ICA" postdoc interested
in computational cognition!

http://www.cfccm.dk/

The independent context hypothesis

- Challenge: Many natural signals contain multiple agents/contexts
- Need to "blindly" separate source signals = learn contexts
- PCA doesn't work – Then who're you gonna call?: -the mixture busters!

$$x(feature, time) = \sum_k A(feature, k) \; s(k, time)$$