Analysis of fMRI Data by Blind Separation Into Independent Spatial Components

Based on a paper by McKeown *et al.*

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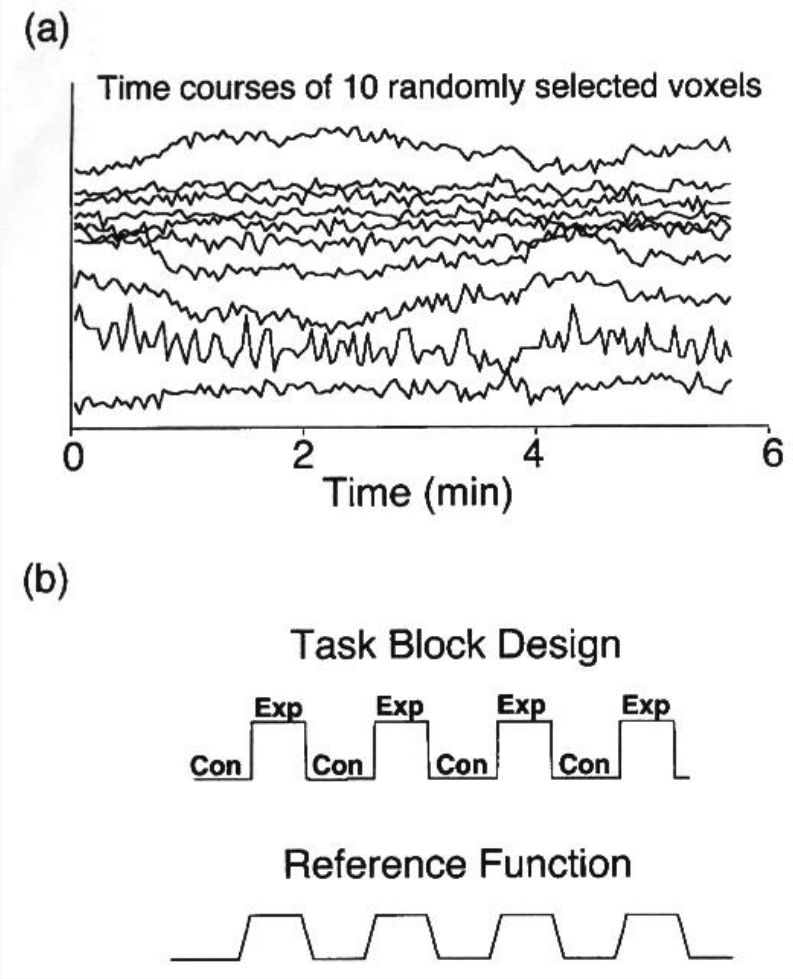
Agenda

- *Introduction*
- *ICA*
- *Experimental methods*
- *Results*
- *Discussion*
- *Further work*

Introduction (1)

- *fMRI = functional magnetic resonance imaging*
- *Many experiments use a block design (CECEC…) with experimental (E) and control (C) tasks.*
- *Signals from thousands of voxels are recorded every 1–3 sec.*

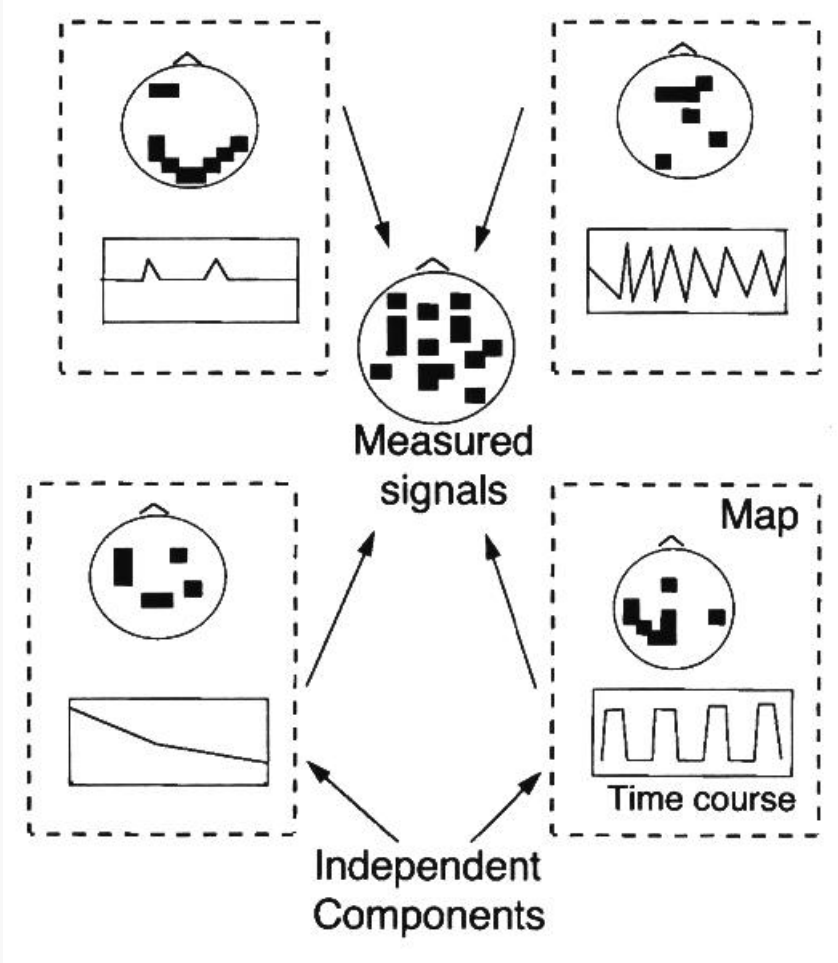


Introduction (2)

- *Yet another abbreviation; blood oxygen level-dependent (BOLD) contrast*
- *Signals have been analyzed using a number of methods*
  - *subtraction, correlation, time-frequency analysis, statistical tests, PCA.*
- *How could ICA be used for this purpose?*

ICA (1)

- *Functional organization of the brain*
  - *Localization and connectionism*
- *Each of separate processes may be represented by one or more spatially independent components.*



ICA (2)

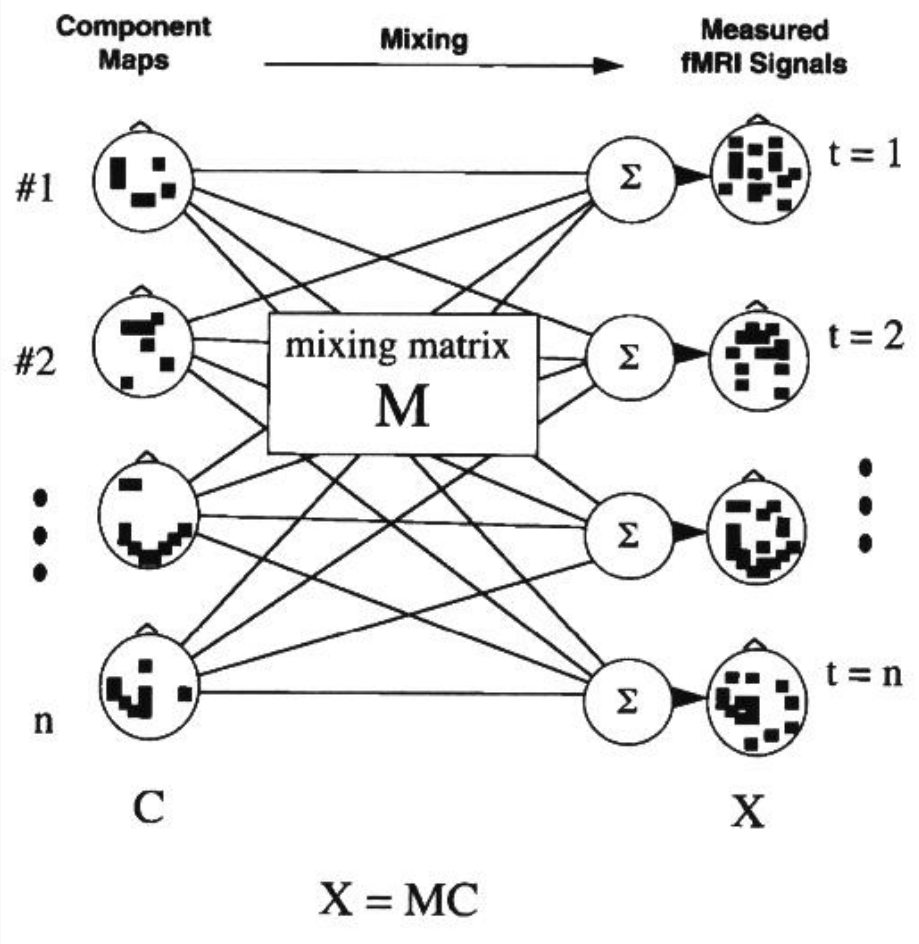
- *Mixing*

  $$\mathbf{X} = \mathbf{MC}$$

- *Unmixing*

  $$\mathbf{C} = \mathbf{WX}$$

- *The unmixing matrix determined using ICA*
- *A simple example can be found in the paper*



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Experimental Methods

- *Two fMRI experiments*
  - *Stroop color-naming task*
  - *A word/number task*
- *Data processing*
  - *Slices collected every 2.5 sec*
  - *No correction for head movement*
  - *Data were temporally smoothed*
  - *Unmixing* **W** *matrix determined using ICA*
  - *Active voxels determined by correlating the signals with a reference function*

Stroop task

- *Subjects were instructed to covertly name the color of each stimulus.*
- *Control blocks*

- *Experimental blocks*

RED **GREEN** **BLUE**

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Word/number task

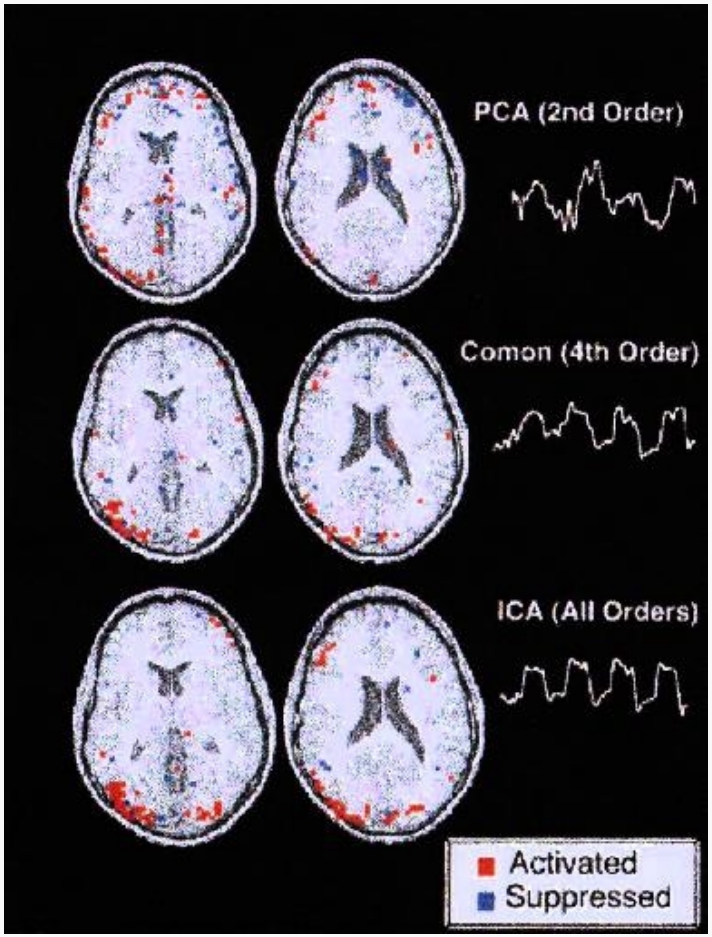
- *Control blocks:*
  - *An asterisk displayed in the screen center*
- *Experimental blocks:*
  - *A word displayed for 2 sec.*
  - *An integer between 100-900 displayed; the subject was to mentally add successive 7s to it while still remembering the word*

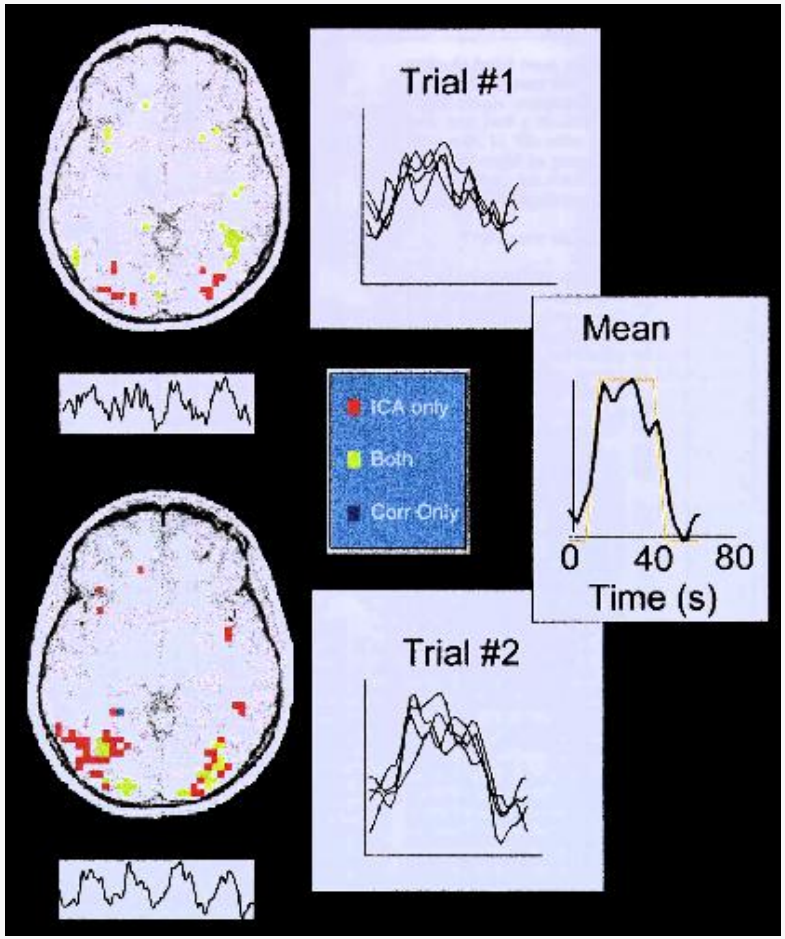
Results (1)

- *The distributions of the ICA component contributions were similar across trials*
- *ICA contributions were quite different from the PCA contributions*
- *One ICA component always highly correlated with the reference function*

  => *We'll call this the consistently task-related (CTR) component*

Results (2)





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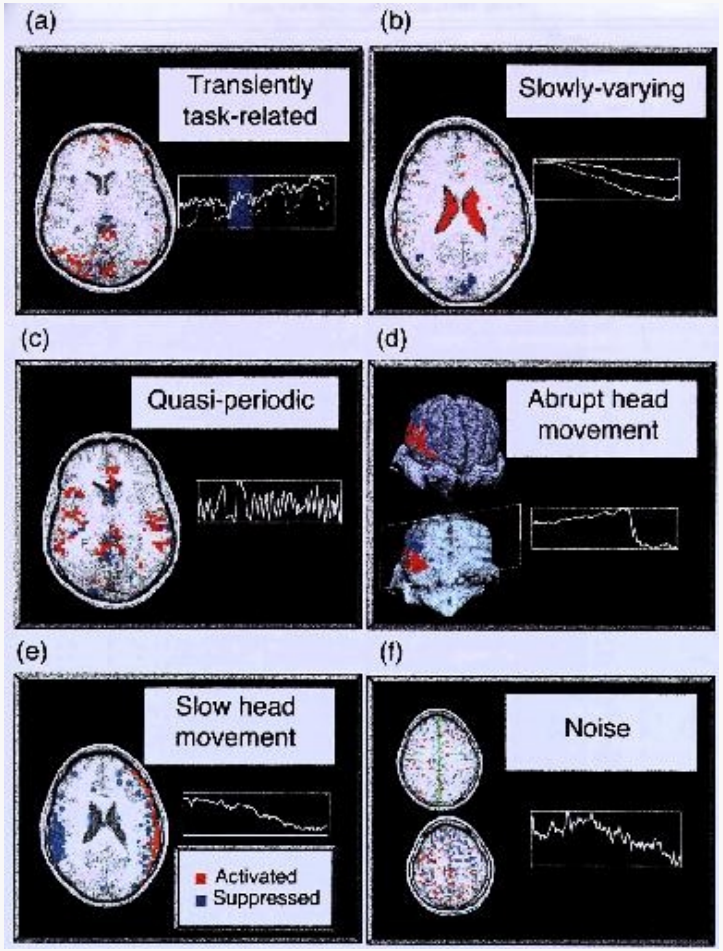
Results (3)

- *Components in addition to CTR*
  - *Transiently task-related (TTR)*
  - *Slowly varying*
  - *Quasi-periodic*
  - *Abrupt head movement*
  - *Slow head movement*
  - *Noise*



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Discussion (1)

- *ICA can be used to reliably separate fMRI data sets into meaningfull components*
  - *Consistently and transiently task-related physiological changes*
  - *Nontask-related physiological phenomena*
  - *Machine or movement artifacts*
- *ICA also produces quasiperiodic components (periods between 10–20 sec.)*
  - *These may be aliased higher frequency signals or related to physiological mechanisms*

Discussion (2)

- *The algorithm is capable of blind separation into independent components*
- *Interpretation of those components requires additional information*
- *The method is able to discern activations that could not be predicted*
- *Limitations:*
  - *The actual fMRI processes may be nonlinear*
  - *The spatial independence may not always be the desired representation for all purposes*

Further Work

- *The smallest ICA components seem to be noise, yet we cannot be sure*
- *It is possible to detect movement artifacts, but there is no straightforward way to compensate movements*
- *Methods for testing the reliability of the algorithm are needed*