Exploring Cerebrovascular Dynamics in the Human Brain

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Introduction

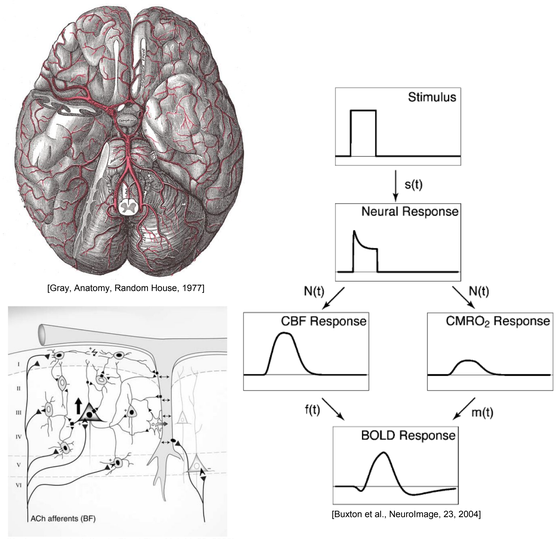
- Understanding the regulatory mechanisms of cerebral blood flow (CBF) and its dysfunction remains a central topic in the neurological scientific literature
- Ample evidence now indicates that certain factors related to age, disease, and medication can dramatically alter cerebro-vascular regulation (Tablet 1)
- Studying the effects of these factors on the living human brain may be possible by exploratory analyses of functional neuro-imaging modalities, e.g., MRI and PET

Methods

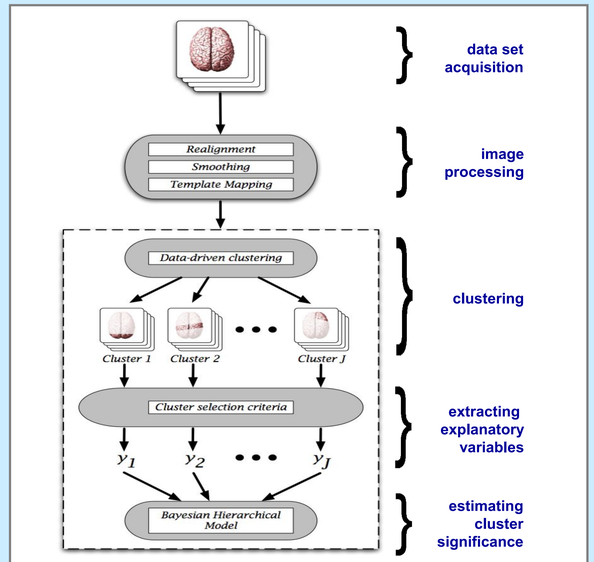
- We propose a unified exploratory method for the analysis of the cerebrovascular response to event-related stimuli as measured by the blood oxygen level-dependent (BOLD) MRI signal (Tablet 2)
- A key difficulty in employing exploratory analysis methods is that after the voxels have been clustered into groups having similar dynamics, the statistical significance of each cluster remains unknown
- We apply a modern Bayesian technique to calculate each cluster's significance in the overall hierachical structure of the data (Tablet 3)

Data acquisition and analysis

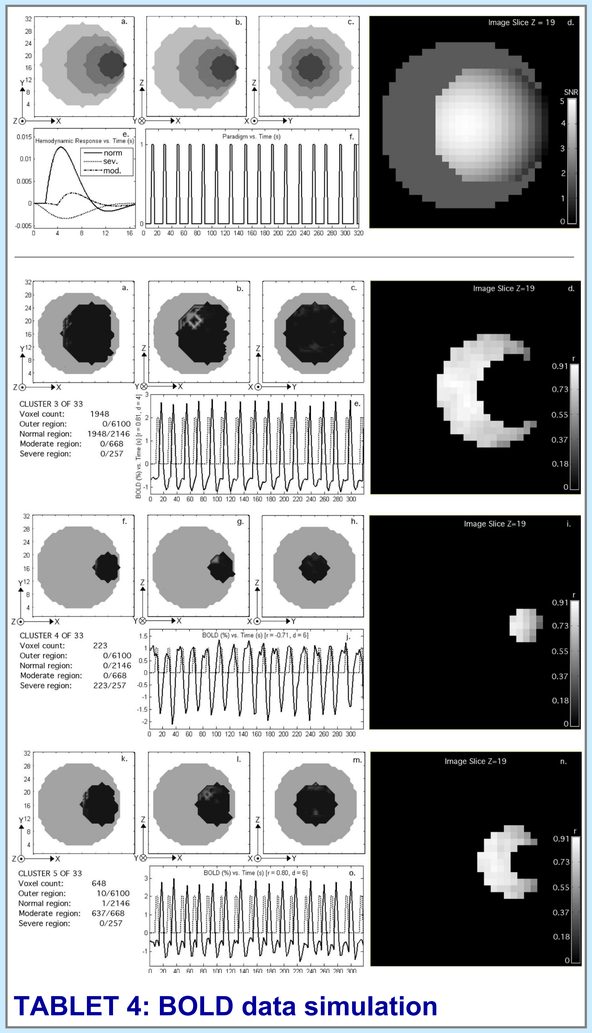
- 25 data sets from 6 normal subjects (28-55)
- Visually cued event-related hand motor task
- 1.5 T MRI scanner (SE-EPI pulse sequence)
- Simulated data using a phantom noise model
- Clustering using fuzzy *k*-means algorithm[1]
- Temporal feature: centroid cross-correlation[2]
- Spatial feature: cluster contiguity[2]
- Statistical inference: Bayesian hierarchical model[3]
- Model parameters are obtained by Markov Chain Monte Carlo simulation



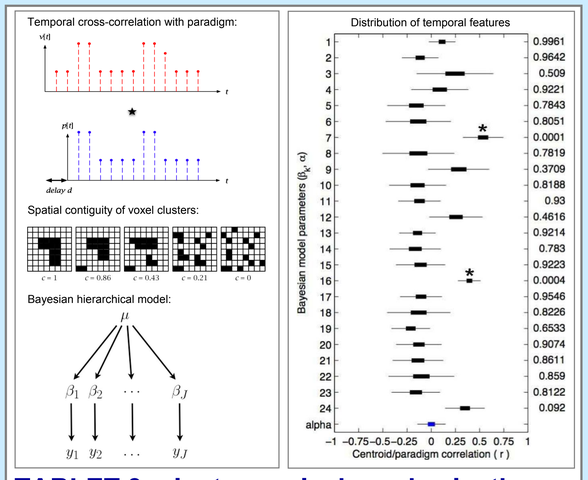
TABLET 1: cerebral blood flow regulation



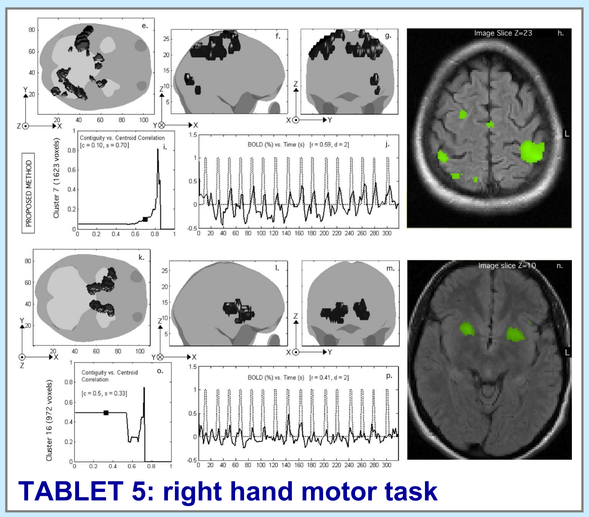
TABLET 2: exploratory analysis method



TABLET 4: BOLD data simulation



TABLET 3: cluster analysis and selection



TABLET 5: right hand motor task

Results and Conclusion

Simulated data (Tablet 4)

- Designed simulations using reported BOLD response characteristics in imaging studies
- Proposed method was capable of distinguishing the 3 response signals used
- Classical hypothesis testing found fewer responding voxels and did not distinguish between positive responses (norm., mod.)

Event-related MRI data (Tablet 5)

- The proposed method agreed well with hypothesis testing; moreover, it distinguished between various responding regions (e.g., motor cortex, putamen, and cerebellum) based on their temporal characteristics

Conclusion

- The proposed exploratory method provides an objective framework to identify voxel patterns in neuroimaging data and may be useful to study CBF regulation and its dysfunction

Short References:

1. Jarmasz, M *et al.* (2002). Exploring regions of interest with cluster analysis. *Artif. Intell. Med.*, vol 25, p 45-67.

1. Gómez-Laberge, C *et al.* (2008). Selection criteria for the analysis of data-driven clusters in cerebral fMRI. *IEEE T. Biomed. Eng.*, vol 55, p 2372-2380.

1. Gelman, A *et al.* (2004). *Bayesian Data Analysis*, 2nd ed., Boca Raton, USA: Chapman & Hall/CRC press.

Acknowledgements: This research was supported by the Behavioural Research and Imaging Network in partnership with the Ontario Research Fund, and by the Heart and Stroke Foundation Centre for Stroke Recovery