Neuroinformatics

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May 1, 2003

Introduction

- Neuroinformatics = Neuroscience + informatics

- Brede neuroinformatics toolbox and database

- "Modeling of activation data in the BrainMap database: Detection of outliers". *Human Brain Mapping* 15(3):146–156, 2002 March.

- "Finding related functional neuroimaging volumes". *Artificial Intelligence in Medicine*, 2003. In print.

Brede neuroinformatics databases

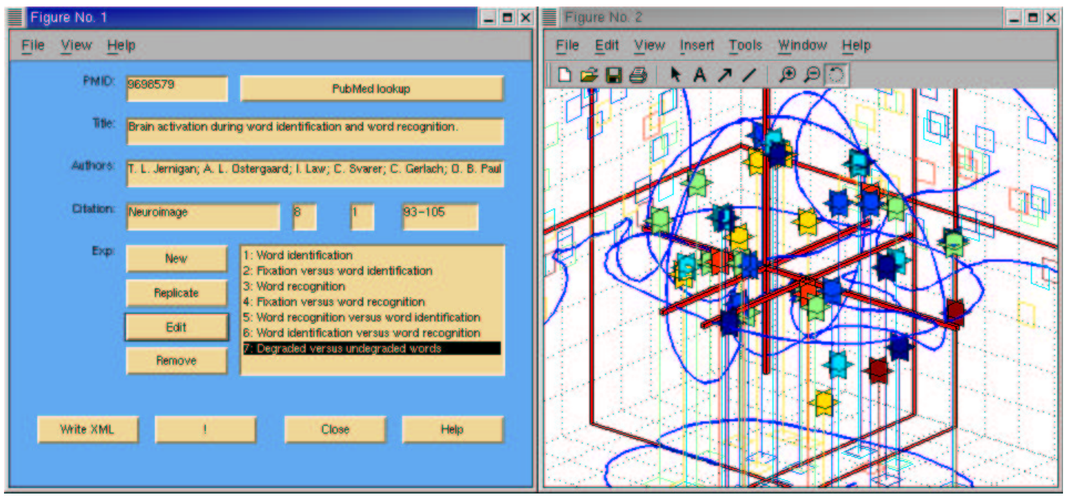


Figure 1: Screenshot of main window of Matlab program for data entry of (Jernigan et al., 1998).

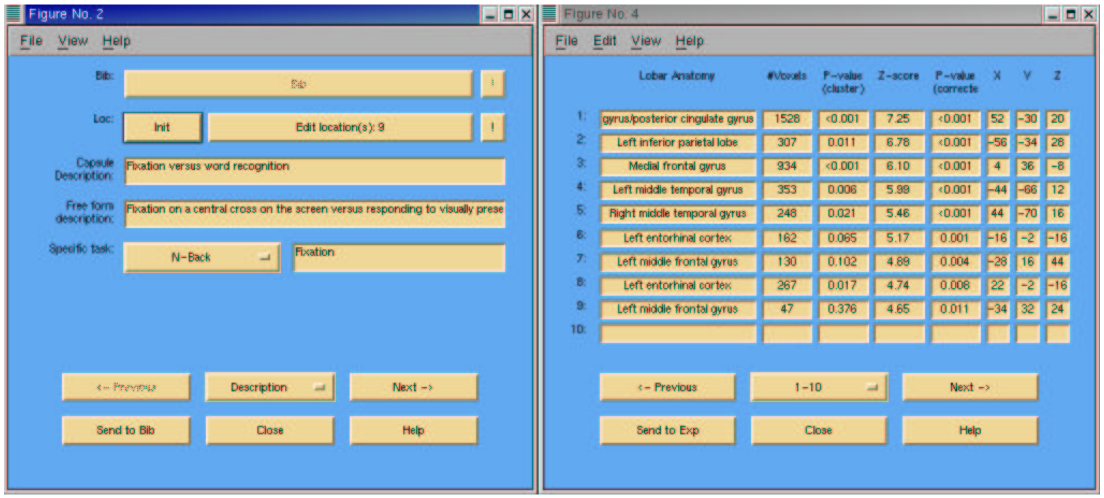
Brede neuroinformatics database

Main component: Stereotactic coordinates.

Bibliographic information taken from PubMed,

Linked to other databases: PubMed, MeSH, fMRIDC, SenseLab.

"Poor man's XML" (pXML): Database kept in a simplified version of XML, distributable on the internet



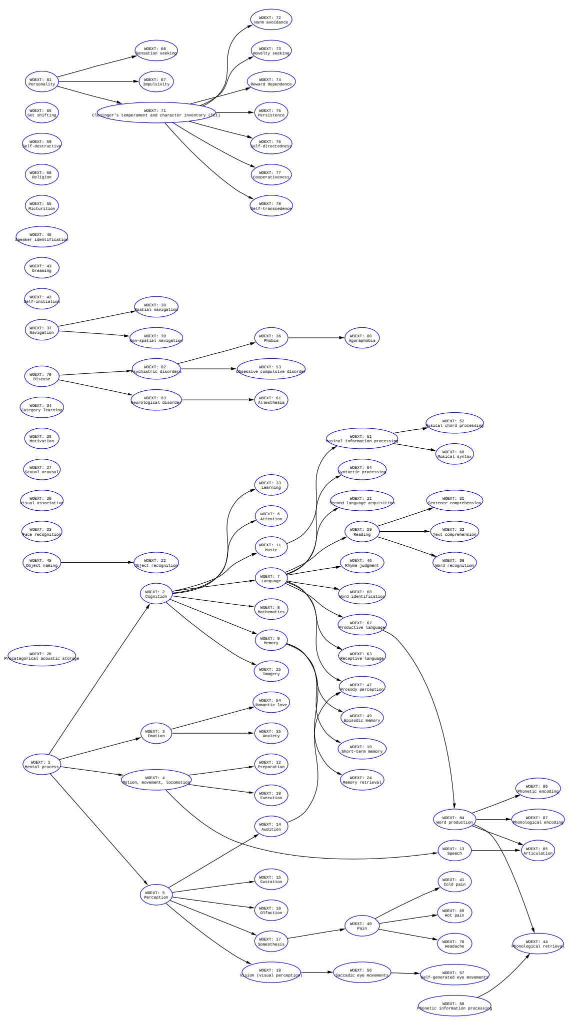
Brede data model heavily inspired by BrainMap database (Fox and Lancaster, 1994): Paper (bibliographic information), experiment (summary image, paradigm, stimulus/response), location (stereotactic coordinates).

	BrainMap	Brede
Papers	225	80
Experiments	771	251
Locations	7683	1677
Year	1985–1998	1996–2003

Data entry with a Matlab program for the information in "experiments" and "locations".

Supplement to BrainMap

External components



External components, e.g., cognitive components “Cold pain”, “Alzheime disease”, “BZ site GABA-A receptor”

External components represented in a directed acyclic graph

Corresponding to MeSH (NLM Medical Subject headings), linking to MeSH were equivalent item exists

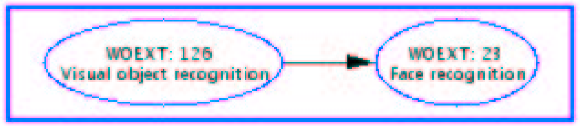
Presently 274 components

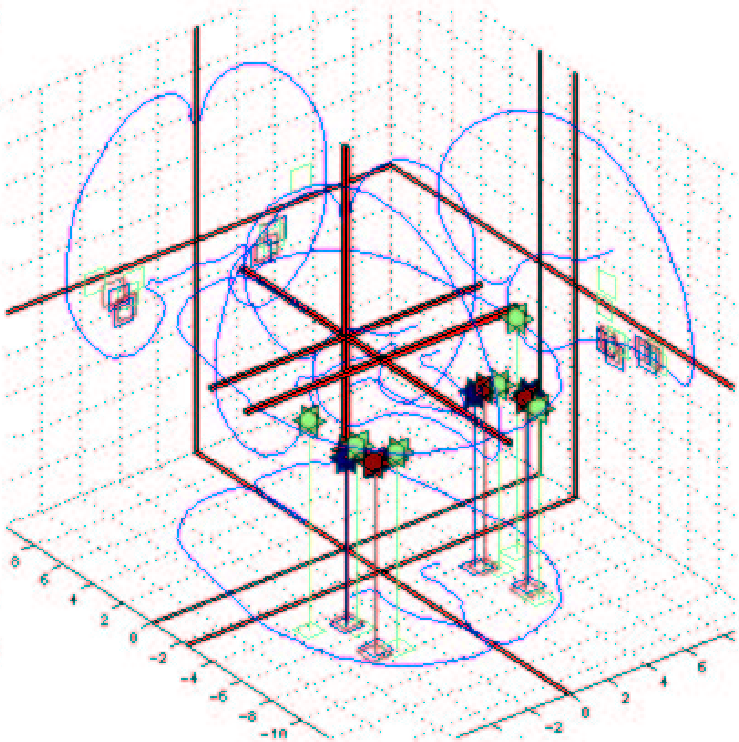
WOEXT: 23. **Face recognition**.
Processing of face images.

Parents	Siblings	Children
Visual object recognition		

Experiments:

1. **Face visual object**. *Visual objects: Faces versus building*. WOEXP: 11.
I Levy; U Hasson; G Avidan; T Hendler; R Malach. *Center–periphery organization of human object areas.*. *Nat Neurosci* **4**(5):533–9, 2001.
PMID: 11319563. WOBIB: 5.
2. **Photographs of faces versus houses and chairs**. *Conjunction between passive viewing and delayed match–to sample of gray–scale photographs versus scrambled pictures and faces versus houses and chairs, with matching choice indicated by pressing a button with the right of left thumb*. WOEXP: 91.
A. Ishai; L. G. Ungerleider; A. Martin; J. V. Haxby. *The representation of objects in the human occipital and temporal cortex.*. *J Cogn Neurosci* **12 Suppl 2**:35–51, 2000.
PMID: 11506646. FMRIDCID: 2–2000–1113D.
WOBIB: 28.
3. **Front–face**. *Line drawings of front face versus line drawings of tumblers*. WOEXP: 123.
U. Hasson; T. Hendler; D. Ben Bashat; R. Malach. *Vase or face? A neural correlate of shape–selective grouping processes in the human brain.*. *J Cogn Neurosci* **13**(6):744–53, 2001.
PMID: 11564319. FMRIDCID: 2–2001–111P8.
WOBIB: 36.



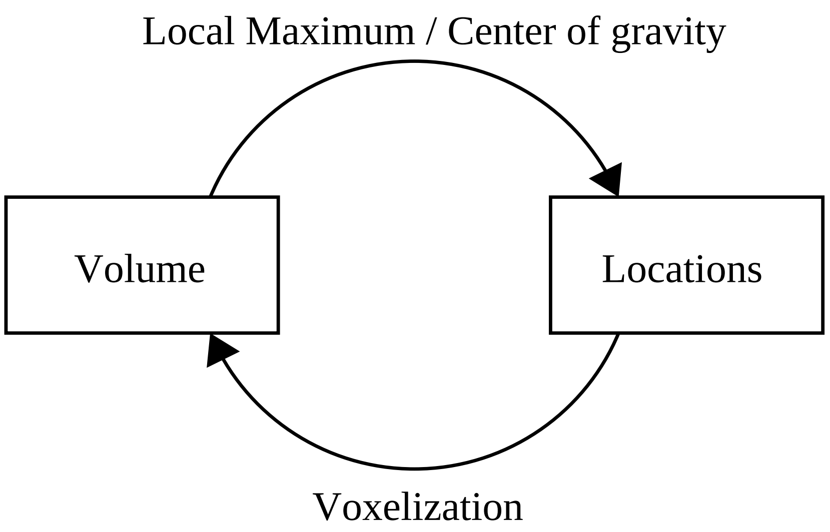


Web-pages generated for each component

Corner Cube visualization (Rehm et al., 1998) with experiments that relates to the specific external component.

Clickable graphs generated with *dot* (Koutsofios and North, 1996).

Modeling locations and volumes



Regard the "locations" as being generated from a distribution $p(\mathbf{x})$, where $\mathbf{x}$ is in 3D Talairach space.

Kernel methods (N kernels centered on each object: $\boldsymbol{\mu}_n$) with homogeneous Gaussian kernel in 3D Talairach space $\mathbf{x}$

$$\hat{p}(\mathbf{x}) = \frac{(2\pi\sigma^2)^{-3/2}}{N} \sum_n^N e^{-\frac{1}{2\sigma^2}(\mathbf{x}-\boldsymbol{\mu}_n)^2}$$

σ^2 fixed or optimized with leave-one-out cross-validation.

Condition on, e.g., anatomical label, behavioral domain c: $p(\mathbf{x}|c)$

Anatomical atlases

(precuneus) precuneus

Asymmetry: −0.09005 (left: −1, right: +1)

SPM ANALYZE volume (MNI, symmetric,
Sigma=4.44769mm, 79 x 95 x 68, 2.0mm x 2.0mm x 2.0mm)
– precuneus–mni–sym.hdr (1 Kb)
– precuneus–mni–sym.img (2042 Kb)

VRML2 file (250 Kb)

Talairach			**BrainMap**		
x	**y**	**z**	**Paper**	**Exp**	**Loc**
−2	−60	24	27	2	8
−2	−60	20	27	2	9
14	−46	36	29	5	4
12	−55	45	29	5	5
8	−57	36	29	10	4
7	−71	36	29	10	5
18	−57	53	29	11	5
12	−42	45	29	11	6
−18	−48	47	29	11	7
8	−59	51	29	11	8
...	...	...	...	...	...

82 coordinates (total)

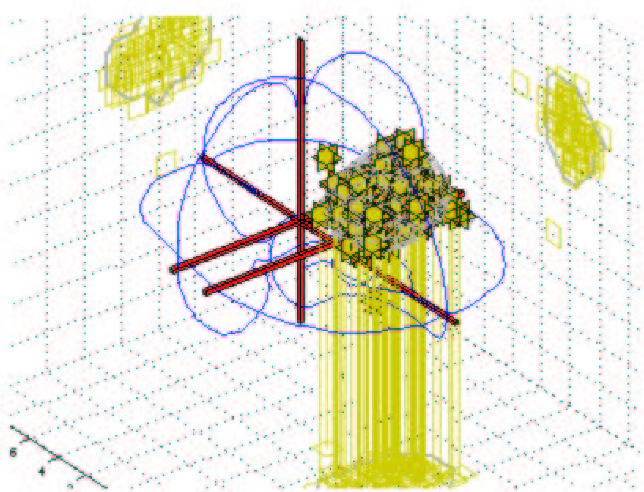


Figure 2: "Precuneus" web-page with data from BrainMap from a part of the 3935 labeled locations.

Conditioning on anatomical label $p(\mathbf{x}|c = \text{precuneus})$.

Extract word and sub-phrases from the "Lobar anatomy" field in BrainMap, e.g., "Occipital gyrus" $\rightarrow$ "occipital gyrus", "occipital" "gyrus".

Web-page for each label with Corner Cube visualization and probabilistic ANALYZE volumes in MNI-space.

Finding related volumes

[WOEXP 89] **Passively viewed scenes**. *Passive viewing of outdoor scenes, furnished rooms, landscapes and landmarks*. WOEXP: 89.

R. Epstein; N. Kanwisher. *A cortical representation of the local visual environment.* . *Nature* **392**(6676):598–601, 1998. PMID: 9560155. DOI: 10.1038/33402. WOBIB: 27.

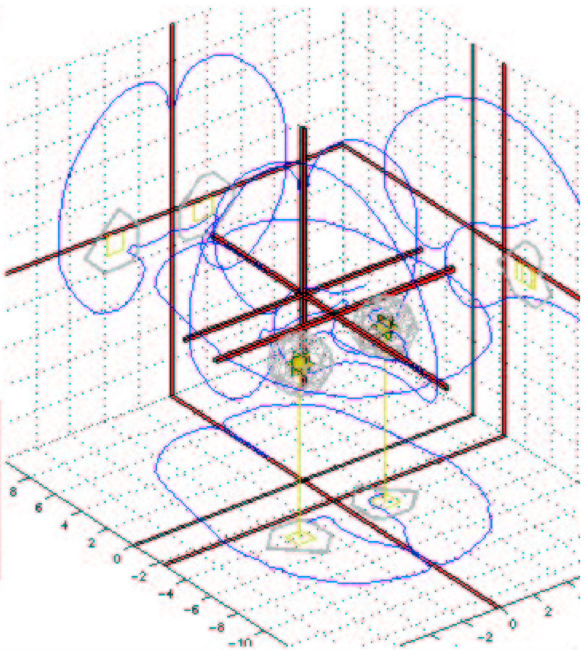
Perception,Vision – Places

Modality: fMRI

Asymmetry: 0.00000 (left: −1, right: +1)

VRML97 file (61 Kb)

x	y	z	Lobar anatomy	Functional area
18	−39	−6		Parahippocampal place area
−34	−42	−6		Parahippocampal place area



Related – positive correlated volumes

+2: 0.80010 (12) **Buildings visual objects**. *Visual object stimuli: Building versus faces*. WOEXP: 12.
I Levy; U Hasson; G Avidan; T Hendler; R Malach. *Center-periphery organization of human object areas.* . *Nat Neurosci* **4**(5):533–9, 2001. PMID: 11319563. DOI: 10.1038/87490. WOBIB: 5.

+3: 0.49922 (42) **Attention to musical instruments versus attention to consonant–vowels**. *Attend to sound and press a button when the target stimulus appeared*. WOEXP: 42.
K. Hugdahl; I. Law; S. Kyllingsbaek; K. Bronnick; A. Gade; O. B. Paulson. *Effects of attention on dichotic listening: an 15O-PET study.* . *Hum Brain Mapp* **10**(2):87–97, 2000. PMID: 10864233. WOBIB: 14.

+4: 0.45377 (97) **Visual object decision**. *Visual object decision with novel and chimeric, natural and artefact line drawings versus pattern discrimination*. WOEXP: 96.
C. Gerlach; I. Law; A. Gade; O. B. Paulson. *Perceptual differentiation and category effects in normal object recognition: a PET study.* . *Brain* **122 (Pt 11)**:2159–70, 1999. PMID: 10545400. WOBIB: 29.

Each experiment a volume: $p(\mathbf{x}|\text{experiment} = \text{WOBIB 89})$ sampled on a fixed 8mm grid.

Location data can be compared to volume data.

Sorted list of similar volumes.

Figure shows result page with automatically generated corner cube visualization (Epstein and Kanwisher, 1998).

Image-based indices: Novelty

4.513130 **Right hand tool use versus grasping and holding**. *Pick up a small cylinder with the right hand using a pair of tongs and transfer it to an other area on a visible magnetic black board with beep sounds as movement cues versus right hand grasping and holding a pair of tongs while visually fixating*. WOEXP: 157.

4.482003 **Correlation with pain unpleasantness**. *Correlation with subjective ratings of unpleasantness with hot pain right volar forearm*. WOEXP: 249.

4.456257 **Large line patterns**. *One–back match–to–sample task with large line patterns versus small line patterns*. WOEXP: 101.

4.302820 **Word repetition**. *Word repetition versus generate word with given first letter*. WOEXP: 33.

Figure 3: The top of the novelty list for Brede experiments. The top novelty is an experiment by (Inoue et al., 2001) with a single activation in $(41, -68, 42)$.

Novelty for an experiment, here: Minimum distance to other volume

Highest scoring in BrainMap:

- (Allison et al., 1994): Only EEG study in the database, only x and y coordinates are given.
- (Reiman et al., 1989): Perhaps a muscle "activation". Correction: (Drevets et al., 1992).
- (Balslev et al., 2002): Perhaps a motion artifact.

Image-based indices: SVD

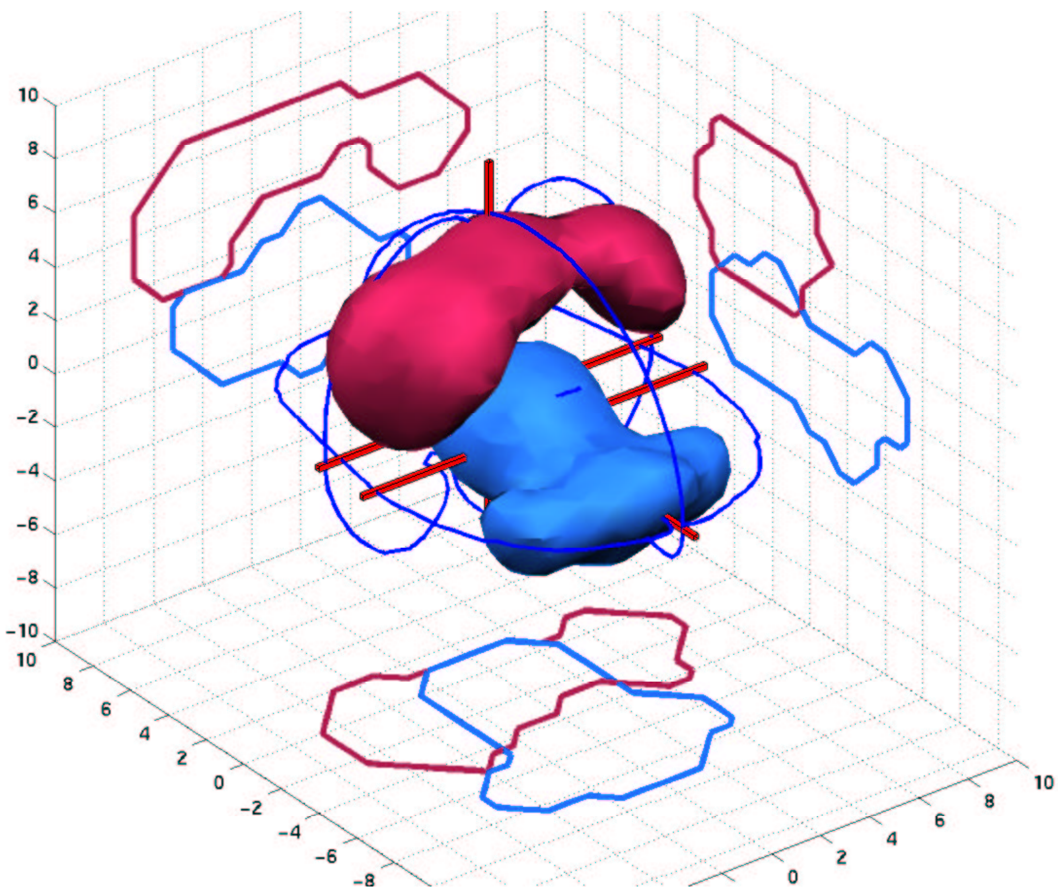


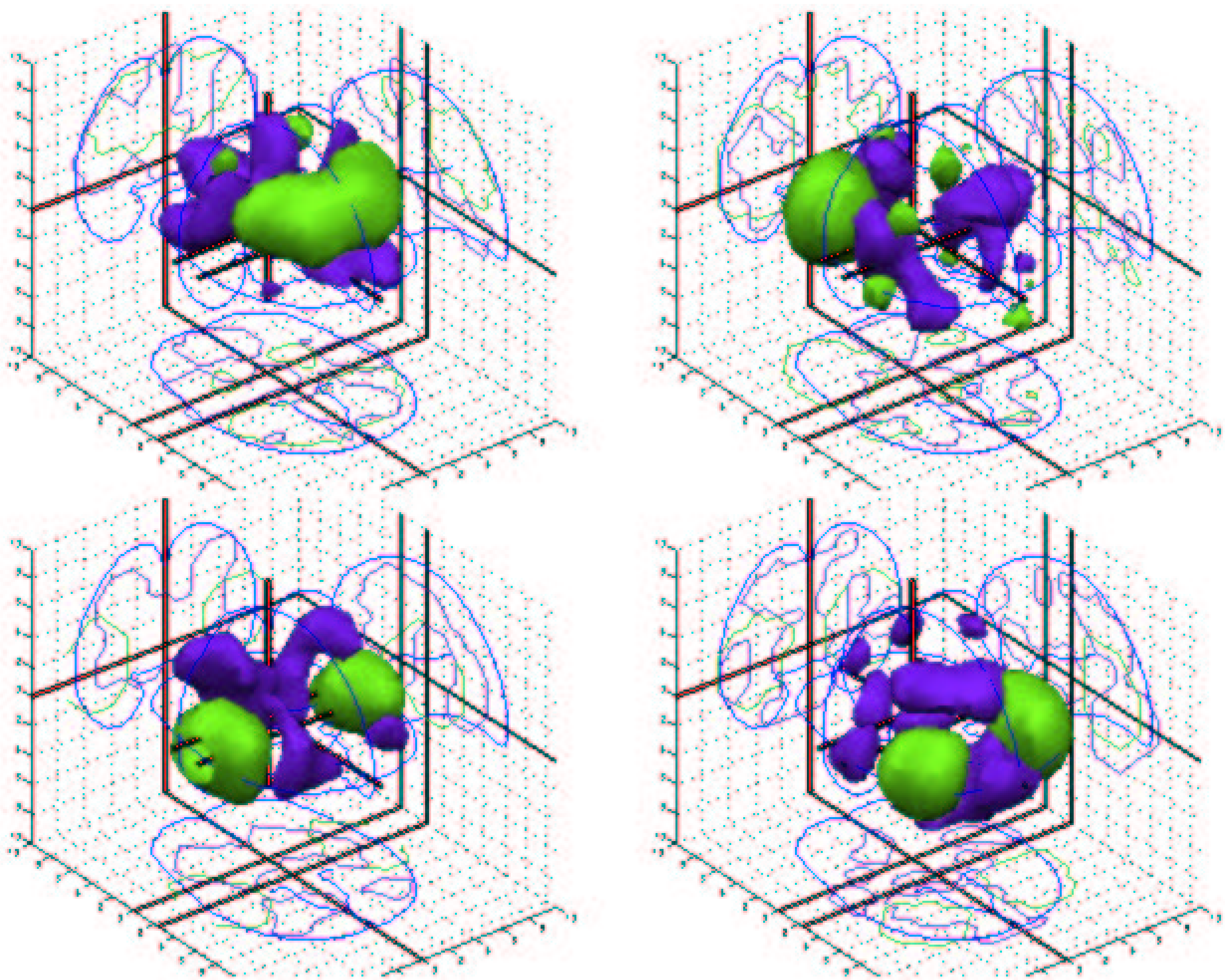
Figure 4: Both ends of the second eigenimage $\mathbf{v}_2$ from an analysis of data from BrainMap.

Singular value decomposition of the (experiment $\times$ voxel) data matrix: $\mathbf{ULV}^{\mathsf{T}} = \mathsf{svd}(\mathbf{X})$. Columns of $\mathbf{V}$ is called eigenimages.

Second eigenimage: One end interpreted as sensorimotor(“upper extremity movements”, “thumb-finger opposition”), other end as visual (“Watch virtual reality right hand grasping objects”).

Higher components have increasing spatial frequency.

Image-based indices: ICA



Independent component analysis of the $\mathbf{X}$(experiment $\times$ voxel) data matrix: $\mathbf{AS} = \text{ica}(\mathbf{X})$. $\mathbf{A}$ is the mixing matrix, $\mathbf{S}$ the sources.

ICA components: hand movement, visuospatial, words/verbs, audition, visual motion.

Figure shows both ends of the third to sixth source images $\mathbf{s}_3, \ldots, \mathbf{s}_6$. Data from Brede.

Image-based indices: Asymmetry

Left dominate	Asymmetry	Right dominate
	0.99902	[WOEXP 185] **Spatial neglect**. *Patients with spatial neglect and right brain damage from infarct or haemorrhage versus right brain damage patients without spatial neglect*. WOEXP: 185.
[WOEXP 5] **Visual artefact object**. *Decision or categorization of visual artefact*. WOEXP: 5.	−0.99219	
[WOEXP 114] **Categorization of artefacts**. *Categorization of visually presented artefacts versus categorization of natural objects, naming of artefacts and pattern discrimination*. WOEXP: 114.	−0.99219	
[WOEXP 137] **Names versus occupation**. *Retrieval and whispering of names from presented photographs of faces. Conjunction between newly learned face and famous face*. WOEXP: 137.	−0.99219	

"Experiment" left/right asymmetry: Count the number of locations in the left side X

$$P_{\text{Bin}} = \sum_{0}^{X} \binom{N}{X} 0.5^{N}. \qquad (1)$$

Normalize the value to $[-1;+1]$ range with $a = 1 - 2P_{\text{Bin}}$

When conditioning on anatomical labels:

- Left dominate (-1): 'motor', 'area', ..., 'broca s area'.
- Right dominate (+1): 'anterior cerebellum',

Conclusion

Modeling 3D Talairach coordinates with kernel density estimators.

Visualization with Corner Cube Environments.

Novelty detection, finding related experiments, unsupervized modeling.

Brede neuroinformatics toolbox: Primarily written in Matlab. Includes the Brede database in XML. http://hendrix.imm.dtu.dk/software/brede/.

Results available on the Internet from hendrix.imm.dtu.dk more specifically http://hendrix.imm.dtu.dk/services/jerne/.

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