Hippocampus and shape analysis

Claire Cury

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TIG symposium for epilepsy

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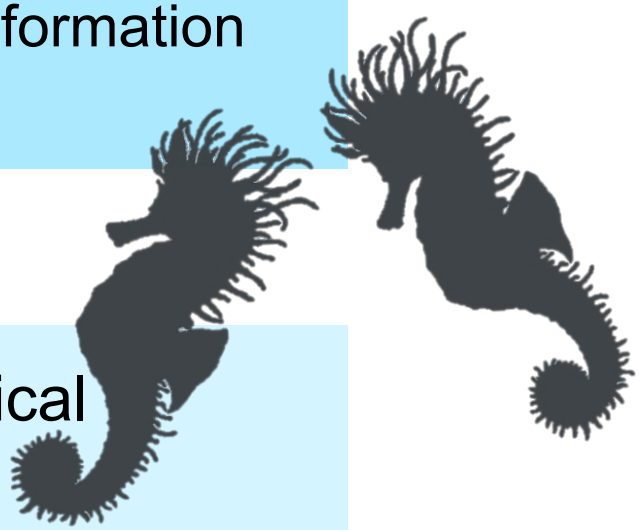
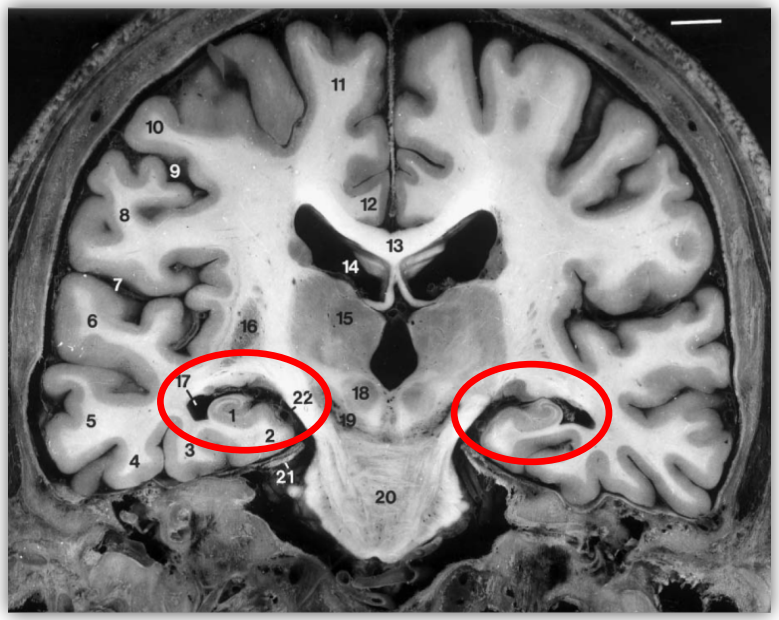
Introduction

- **Position:** Position of the object in its environment.
- **Shape:** 3D edge of an object. Ridge transformation invariant.

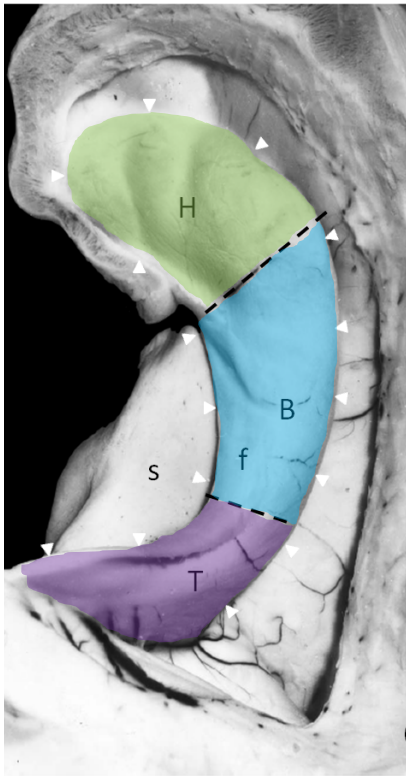


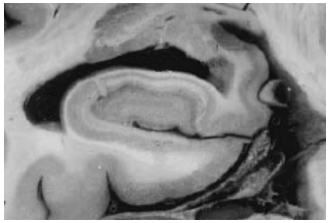
- **Statistical shape analysis** of anatomical structures
  - **Modelisation** of normal and pathological variability.
  - **Prediction** of clinical and biological parameters.

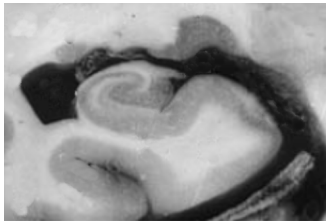
Hippocampus Anatomy

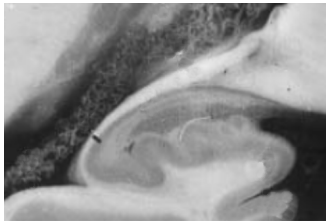


Images: Duvernoy et al, 2005





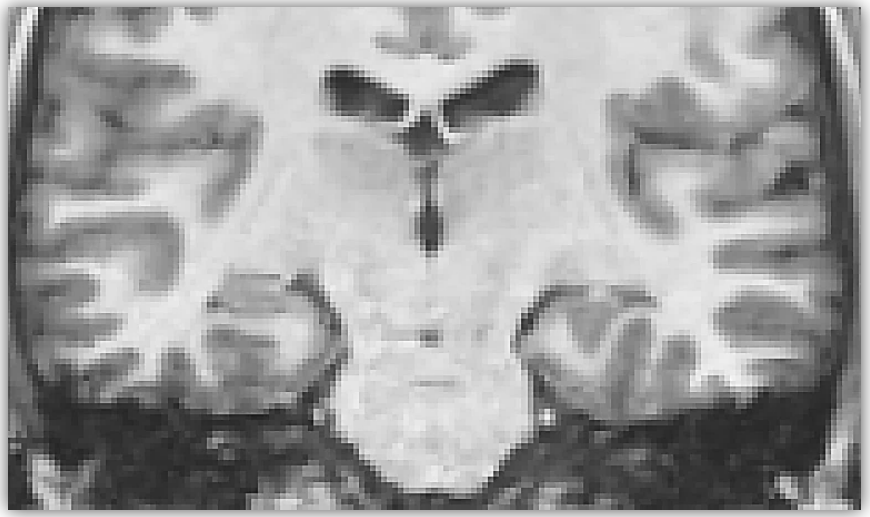




Incomplete Hippocampal Inversion (IHI)

Mainly described in **epileptic patients** **(Barsi et al. 2000; Bajic et al. 2009;…) ~ 50%**

In healthy population **(Bernasconi et al. 2005; Bajic et al. 2008; Gamss et al. 2009) ~ 20%**



Criteria ill-defined

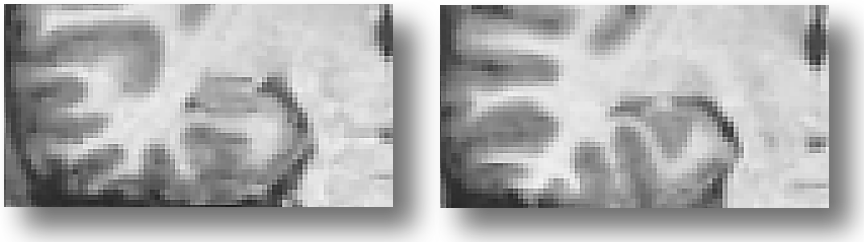
Mix of healthy and controls (non epileptics) **(Gamss et al. 2009)**

Not enough subjects **(Bajic et al. 2008)**

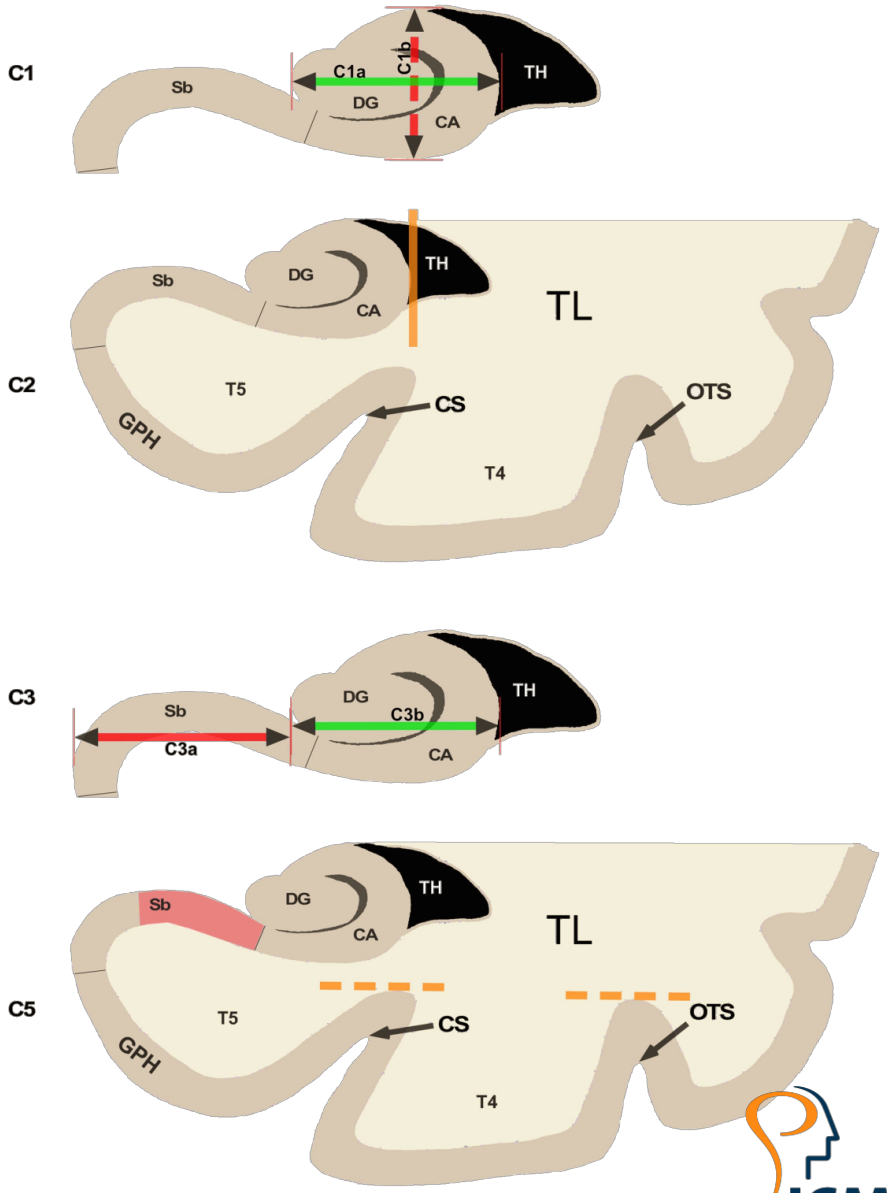
IHI : Criteria

- **C1**: roundness and verticality
- **C2**: collateral sulci
- **C3**: position
- **C4**: subiculum
- **C5**: T4 sulci

- C0, IHI **global** appraisal:
  - **0** : normal aspect
  - **1** : Partial IHI
  - **2** : Total IHI



Cury et al. Frontiers in Neuroanatomy, 2015



IHI : Results on 2000+ young subjects

Smaller volumes for IHI
(**test-*t* = 5,93; *p* = 4,1e-9**).

Volumes (en cm^3)	**IHI**	**No IHI**
Left	2,75	2,95
Right	2,78	2,99

QC seg	**IHI**	**Partial IHI**	**No IHI**
Left	2,06	2,46	2,74
Right	2,38	2,65	2,69

Segmentation quality **deteriorated** by IHI
(t-test, p < 1e-10).

IHI more **habitual** on the **left** side (test du χ^2 , p = 8.10^{-29})

C0	**IHI**
Left	**17.1%** **CI: [15.5%; 18.7%]**
Right	**6.5%** **CI: [5.4%; 7.6%]**

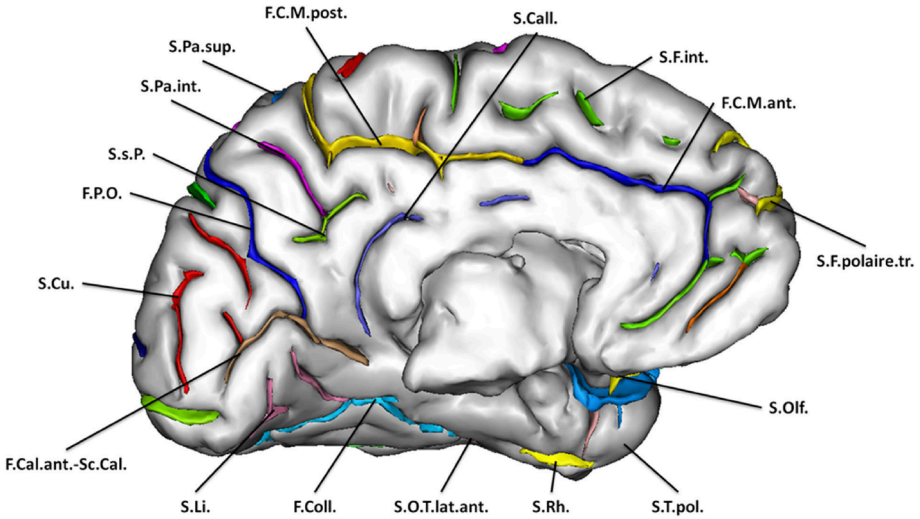
Left vs Right	**Right IHI**
No IHI Left	**1.9%** CI: [1.3%; 2.5%]
Partial Left IHI	0.5% CI: [0.2%; 0.8%]
Left IHI	**4.0%** CI: [3.1%; 4.9%]

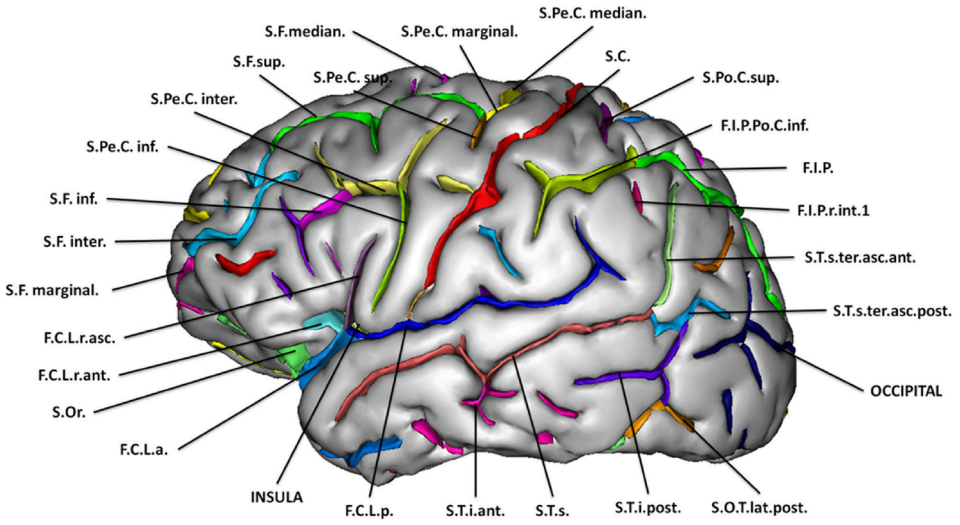
Right unilateral IHI are **occasional** (test du χ^2 , p = 7.10^{-82})

IHI do **not depend** on **gender** or **hand laterality**.

Cury et al. Frontiers in Neuroanatomy, 2015

IHI and sulci : Developmental hypothesis

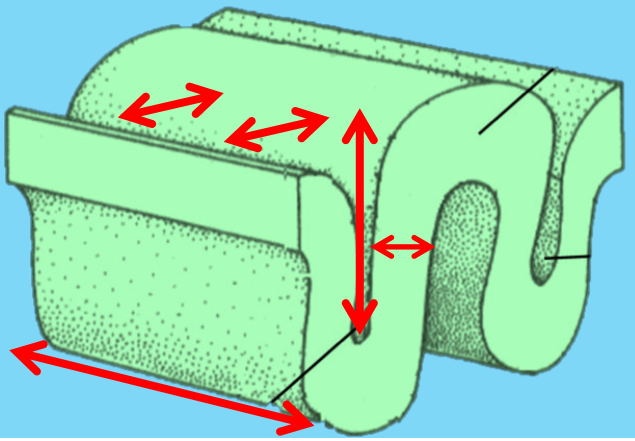




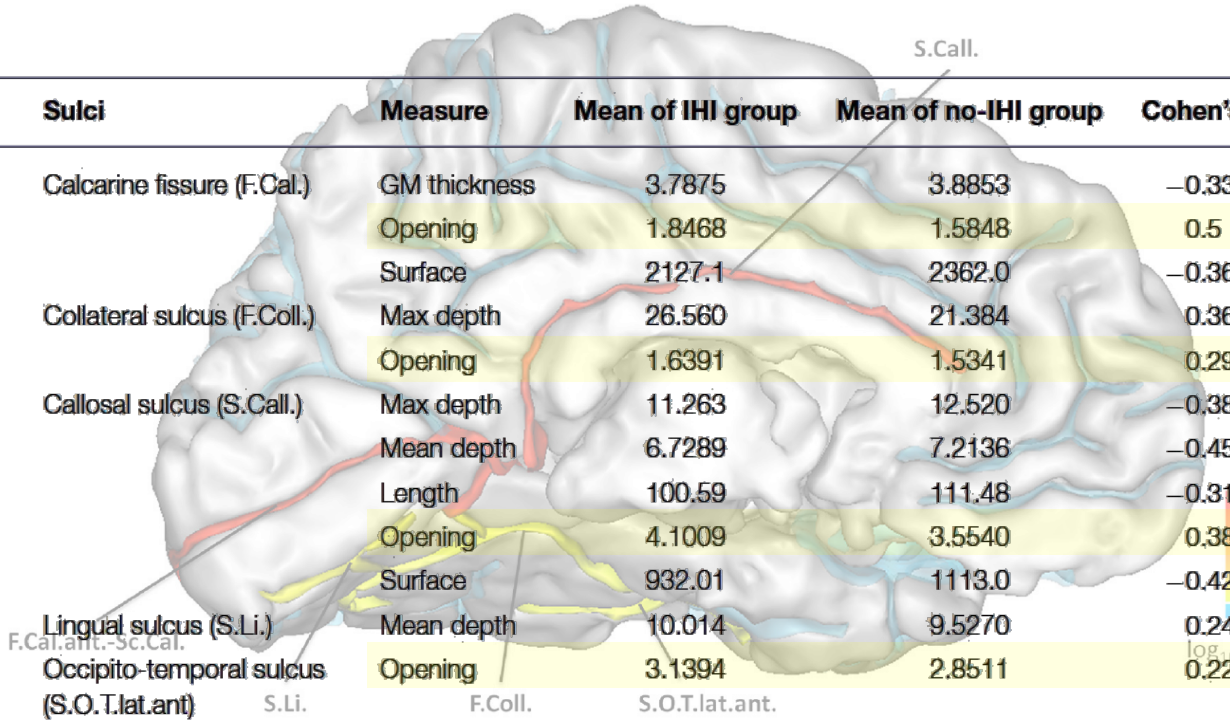
Sulci segmentation and labialisation (Morphologist, Brainvisa).

1705 subjects, 6 measures:

- Surface
- Maximal depth
- Mean depth
- Length
- Grey matter thickness
- Opening



IHI and sulci : Results



	Sulci	Measure	Mean of IHI group	Mean of no-IHI group	Cohen's d	*T*	Corrected *p*-value
Left Hippocampi vs. Left Hemisphere	Calcarine fissure (F.Cal.)	GM thickness	3.7875	3.8853	−0.33	−5.72	1.13e-05
		Opening	1.8468	1.5848	0.5	9.72	8.79e-19
		Surface	2127.1	2362.0	−0.36	−5.89	4.11e-06
	Collateral sulcus (F.Coll.)	Max depth	26.560	21.384	0.36	7.19	8.52e-10
		Opening	1.6391	1.5341	0.29	5.13	2.9e-04
	Callosal sulcus (S.Call.)	Max depth	11.263	12.520	−0.38	−6.41	1.63e-07
		Mean depth	6.7289	7.2136	−0.45	−7.7	2.10e-11
		Length	100.59	111.48	−0.31	−5.5	4.02e-05
		Opening	4.1009	3.5540	0.38	6.9	6.32e-09
		Surface	932.01	1113.0	−0.42	−7.28	4.65e-10
	Lingual sulcus (S.Li.)	Mean depth	10.014	9.5270	0.24	4.37	1.17e-02
	Occipito-temporal sulcus (S.O.T.lat.ant)	Opening	3.1394	2.8511	0.22	4.12	3.62e-02

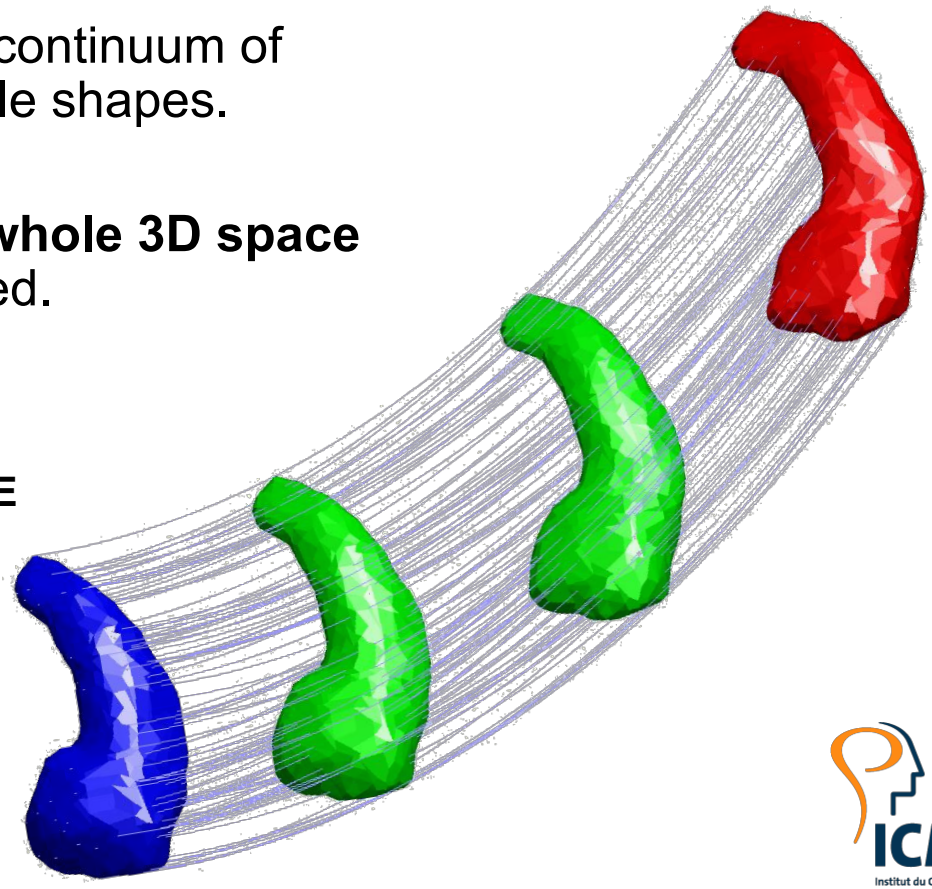
Common point of these sulci: The opening is significantly higher for the IHI group.

Cury et al. Frontiers in Neuroanatomy, 2015

Shape analysis

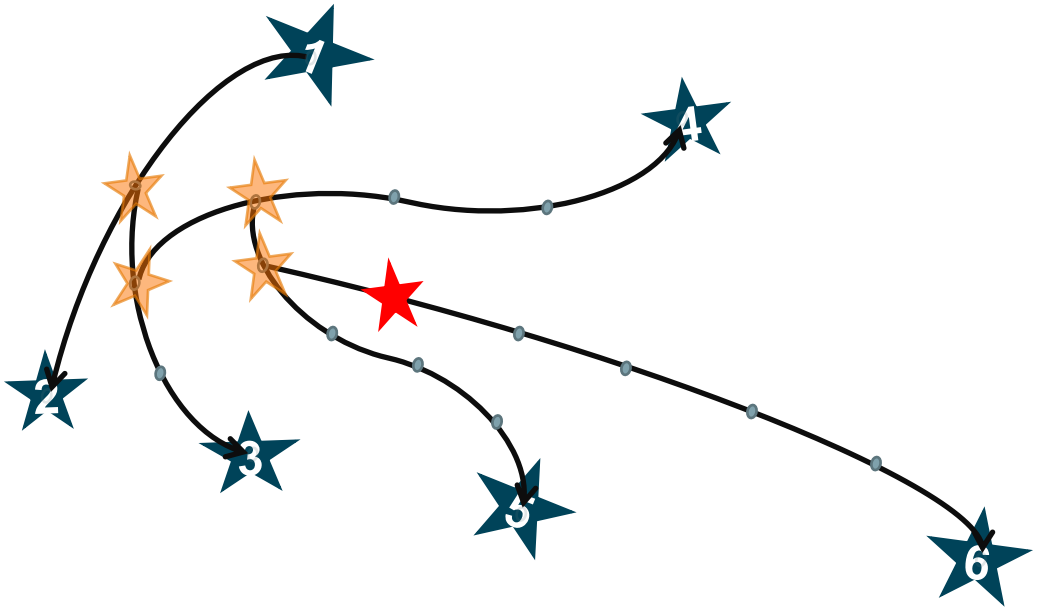
LDDMM Large Deformation Diffeomorphic Metric Mapping : Quantify the differences between shapes.

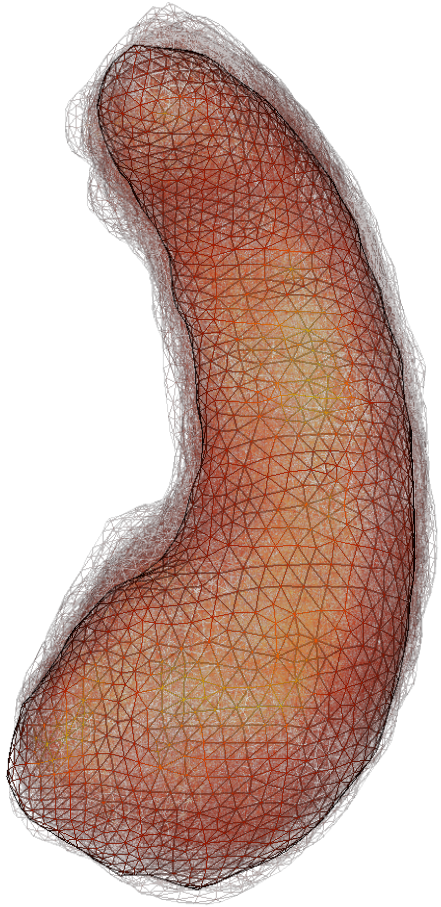
- 2 shapes can be connected by a continuum of intermediate anatomically plausible shapes.
- Diffeomorphic maps **act on the whole 3D space** → spatial organization is preserved.
- ⛔ **EXPENSIVE IN COMPUTATION TIME**



Shape analysis: GroupWise study

Analyse of **shape deformations** from a **centre** of the population.





Prediction of **IHI** scores using the shape information of **1000** hippocampi. (corr = 0.47)

→ Need to improve the prediction of IHI scores using sulci measures

Exemple:
Barycentre of 95 surfaces

Cury et al. Geometric Science of Information, 2014

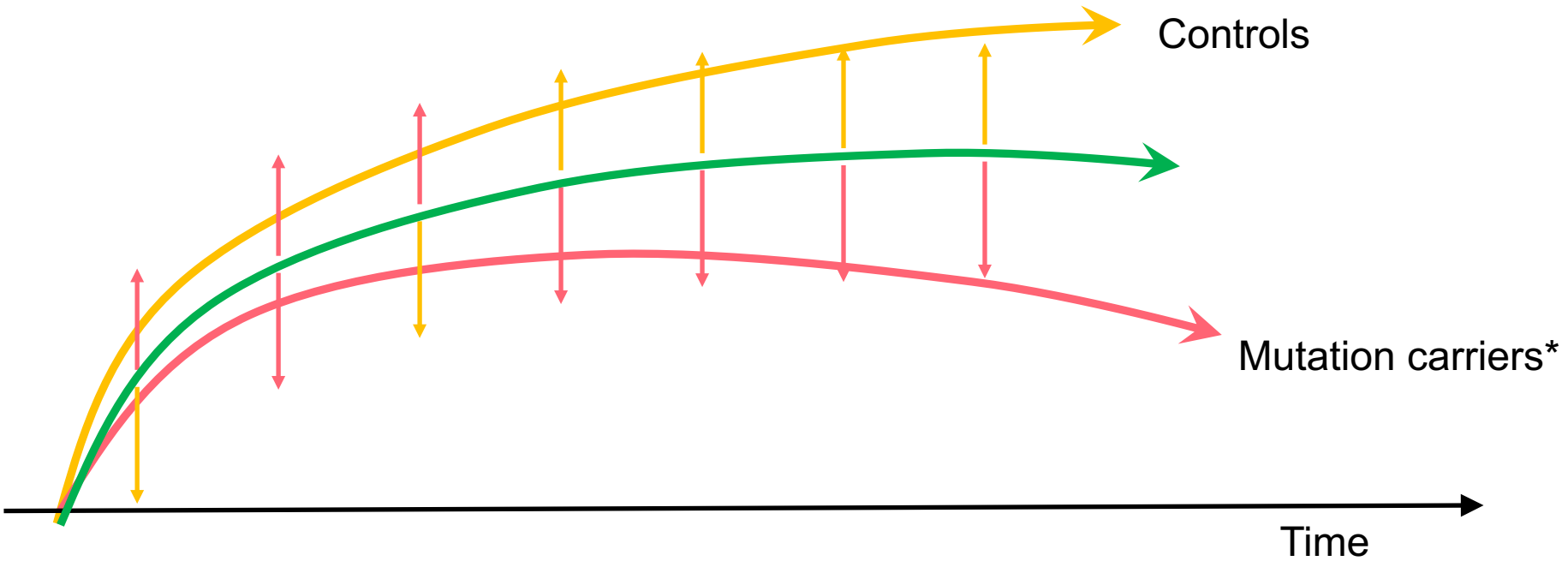
Shape analysis: Spatio-temporal study

Detection of early shape changes in genetic dementia

Neuro-degenerative diseases as AD or FTD have **progressive clinical symptoms** (dementia, memory loss, changes in behaviour,…).

There is evidence of **anatomical changes** [Rohrer et al. 2015] that occur in these diseases much earlier than the onset of these clinical symptoms.

→ Can we detect differences using shape information?



* For genetic form of neurodegenerative disease, the mutation carrier group represent the subject with a mutation on one of the at-risk gene.

Cury et al. SESAMI workshop, MICCAI, 2016

Shape analysis: Spatio-temporal study

Kernel PCA on deformation's parametrisations

Mixed effect model on the Principal Components

fixed effects: MC, EYO, MC x EYO, EYO^2

random effects: family, center, gender

THE **SHAPE** ANALYSIS DETECTS **CHANGES EARLIER** THAN THE VOLUMETRIC ANALYSIS

	p-value for MC status	p-value for EYO int.
1 PC	3e-3	4e-3
2 PCs	3e-3	0.02
3 PCs	< 1e-4	0.02

Wald test every 5 years how long before the EYO we can detect shape differences

PCs (captured var.) \ EYO	-25	-20	-15	-10	-5	0	+5	+10
PC 1 (20.4%)	0.70	0.94	0.60	0.16	8e-3	<1e-3	<1e-3	<1e-3
PC 2 (11.3%)	0.42	0.26	0.16	0.08	0.03	0.01	0.01	0.03
PC 3 (10.8%)	0.29	0.13	0.08	0.06	0.06	0.08	0.25	0.62
PC 1+2 (31.7%)	0.78	0.80	0.77	0.45	0.07	1e-3	<1e-3	<1e-3
PC 1+2+3 (42.5%)	0.76	0.49	0.23	0.05	2e-3	<1e-3	<1e-3	<1e-3
Total thalamus volume [Rohrer et al.]	0·36	0.50	0.47	0.25	0.04	<1e-3	<1e-3	<1e-3
Total thalamus volume	0·38	0.50	0.47	0.24	0.04	<1e-3	<1e-3	<1e-3
Left thalamus volume	0·77	0.97	0.96	0.96	0.69	0.33	0.14	0.10

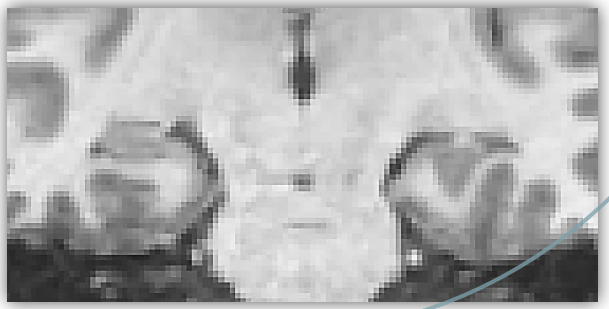
Cury et al. SESAMI workshop, MICCAI, 2016

Conclusion and perspectives

Prediction of the **IHI** scores using the shape information of hippocampi.

Template-based shape analysis method with diffeomorphic deformation : modelling the **anatomical variability** of **1000 hippocampi**.

Better **evaluation** of the **IHI**:
- Detailed
- Robust



Understand the **lateralisation** of the IHI
Genetic of the IHI

Prediction can be improved, using **sulci measures**

Shape analysis Interesting in **longitudinal** studies and for **developmental** studies.
- Follow changes of some biomarker of lesions shape

Great **potential** of **shape analysis** to better understand brain anatomy
- Analysing different brain structures together (hippocampus and sulci)
- Understanding the sulci's opening