



# Hippocampus and shape analysis

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# Hippocampus and shape analysis

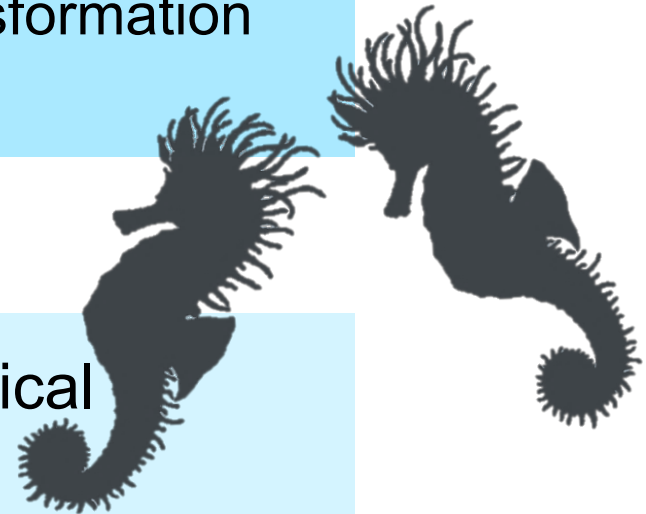
TIG symposium for epilepsy

Claire Cury

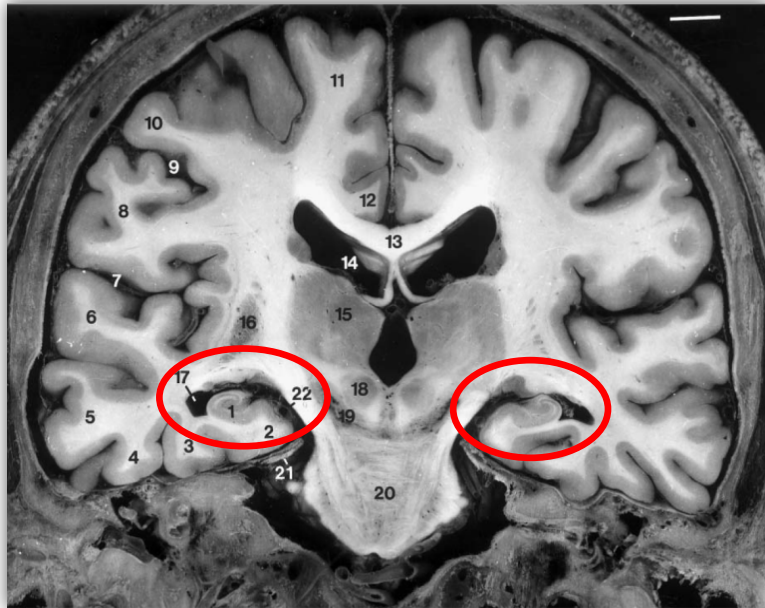
# Introduction

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

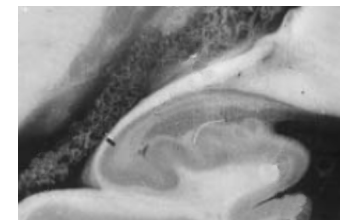
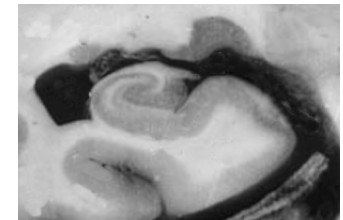
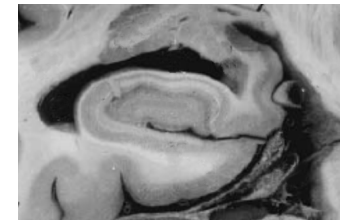
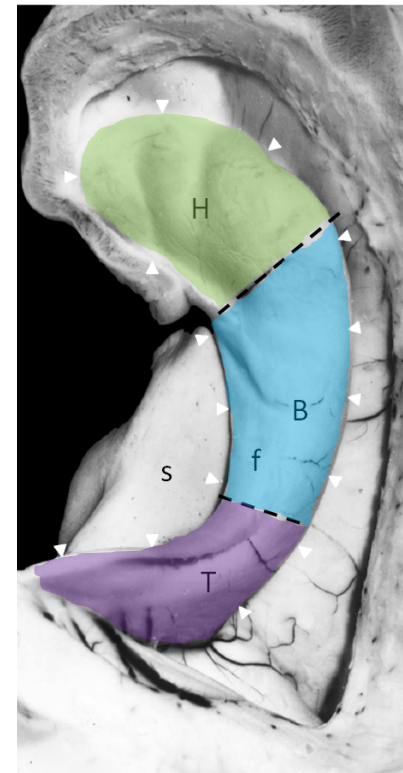
- **Statistical shape analysis** of anatomical structures
  - **Modelisation** of normal and pathological variability.
  - **Prediction** of clinical and biological parameters.



# 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**

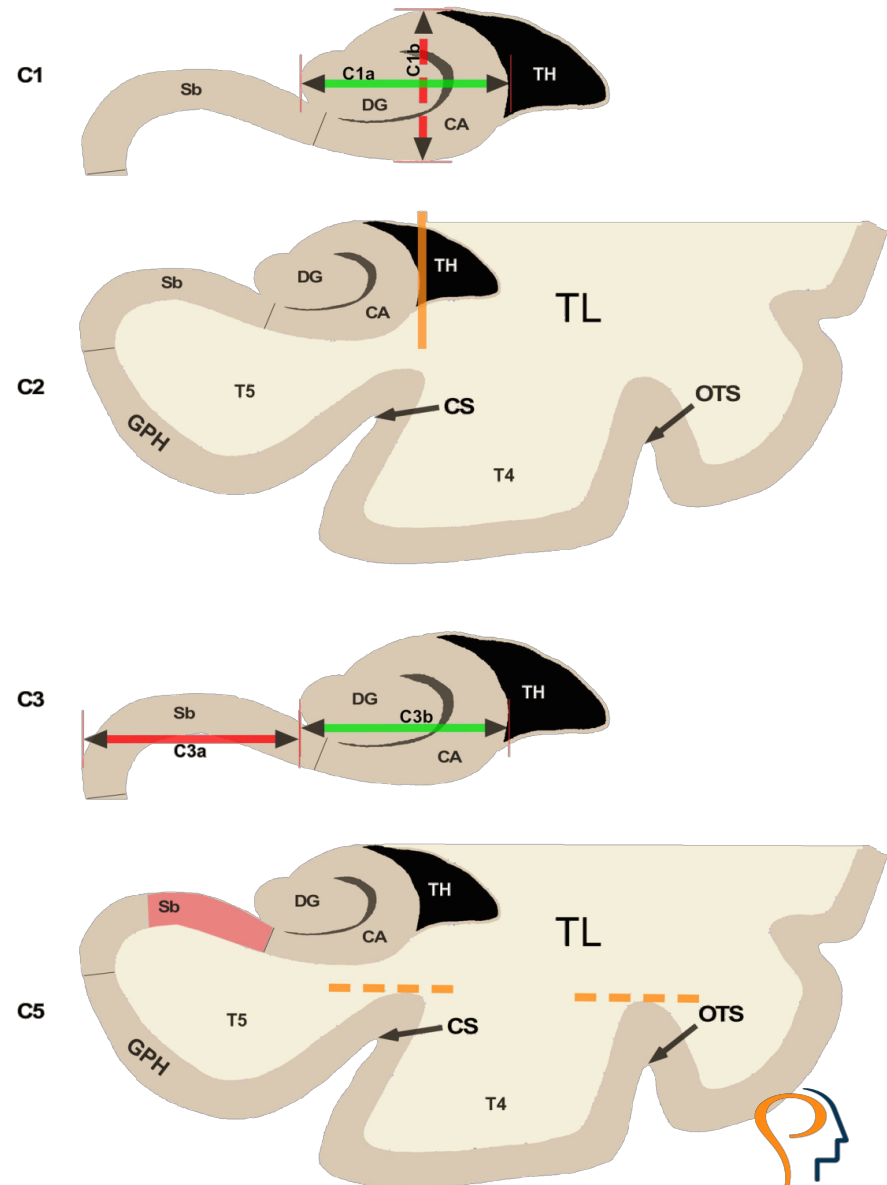
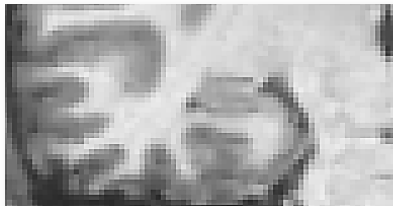
Mix of healthy and controls (non epileptics) (Gamss et al. 2009)

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



# 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
<b>Left</b>	2,75	2,95
<b>Right</b>	2,78	2,99

QC seg	IHI	Partial IHI	No IHI
<b>Left</b>	2,06	2,46	2,74
<b>Right</b>	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  $\chi^2$  ,  $p = 8.10^{-29}$ )

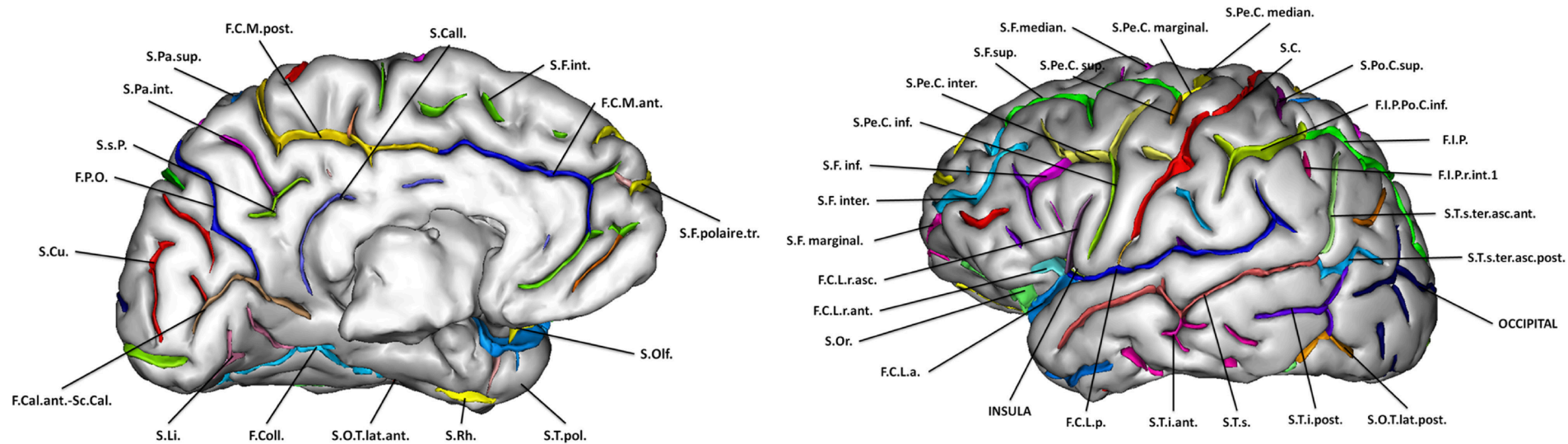
C0	IHI
Left	<b>17.1%</b> <b>CI: [15.5%; 18.7%]</b>
Right	<b>6.5%</b> <b>CI: [5.4%; 7.6%]</b>

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

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

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

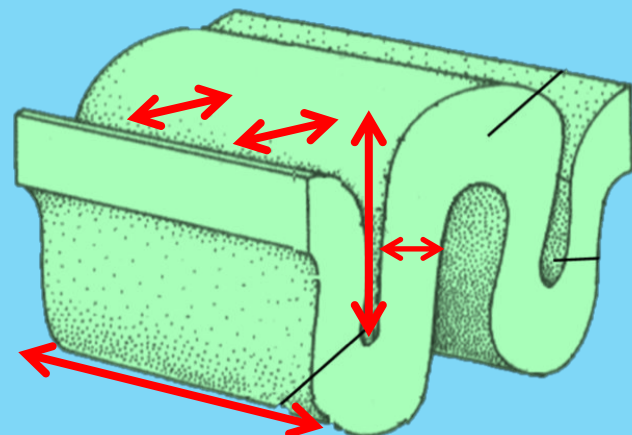
# IHI and sulci : Developmental hypothesis



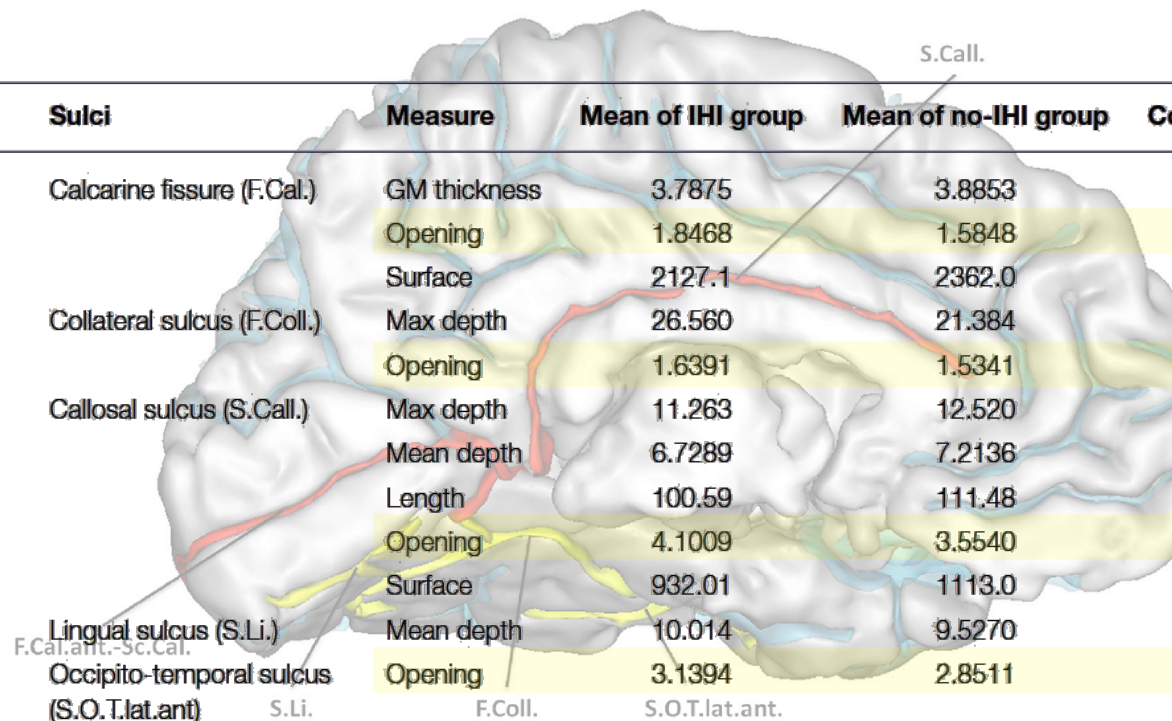
## Sulci segmentation and labialisation (Morphologist, Brainvisa).

**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 <sup>10</sup>	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

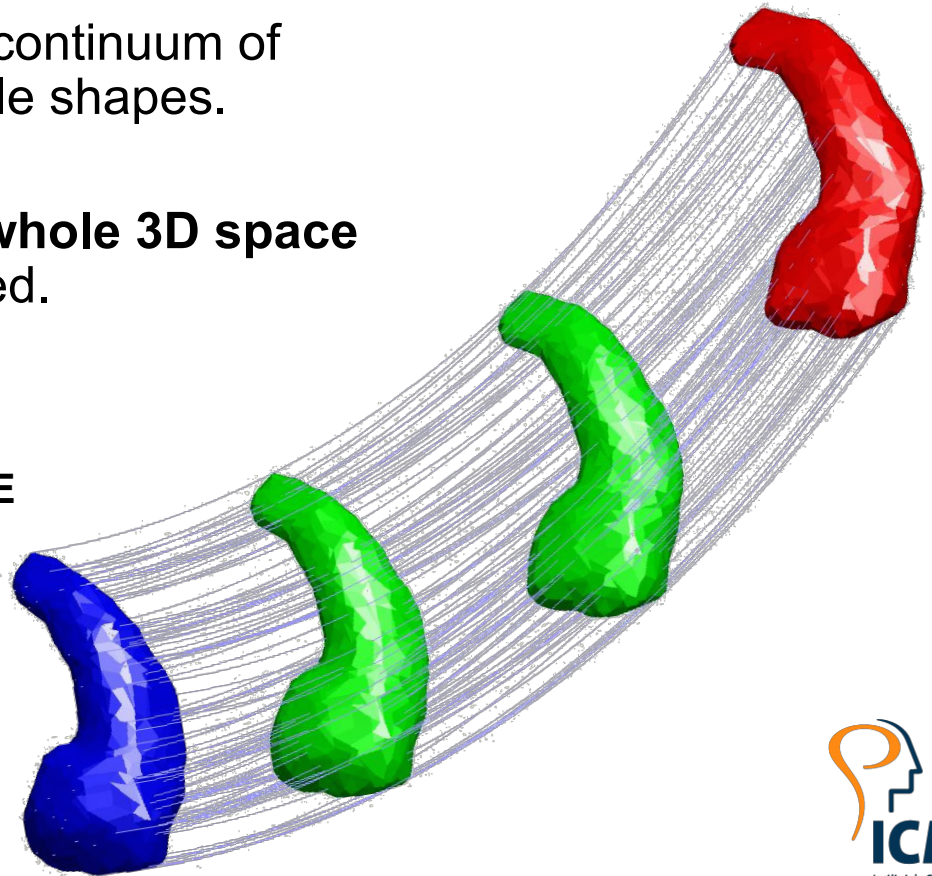
Common point of these sulci: The opening is significantly higher for the IHI group.



# Shape analysis

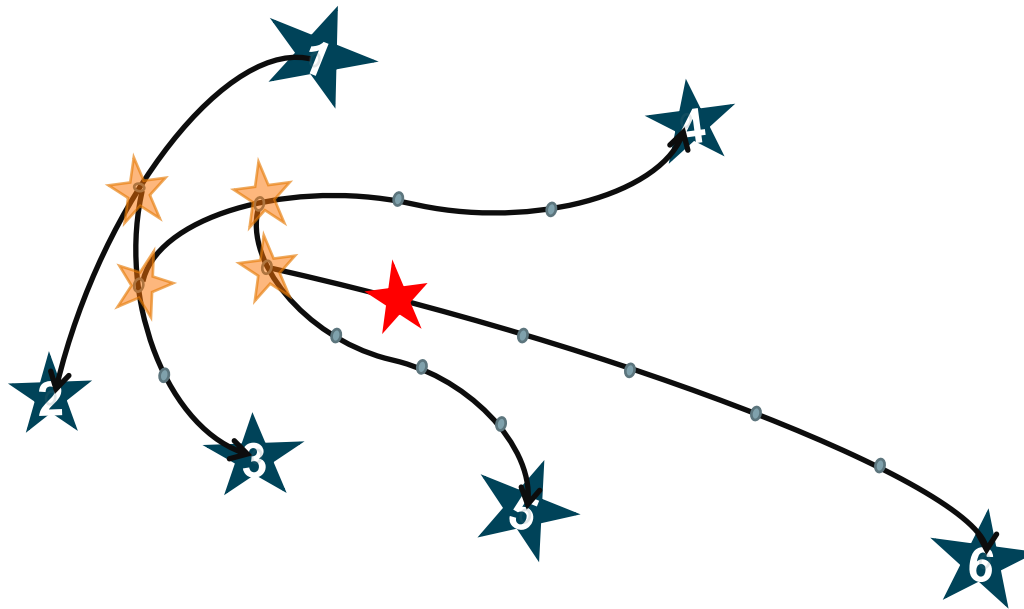
**LDDMM Large Deformation Diffeomorphic Metric Mapping** : Quantify the differences between shapes.

- 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**



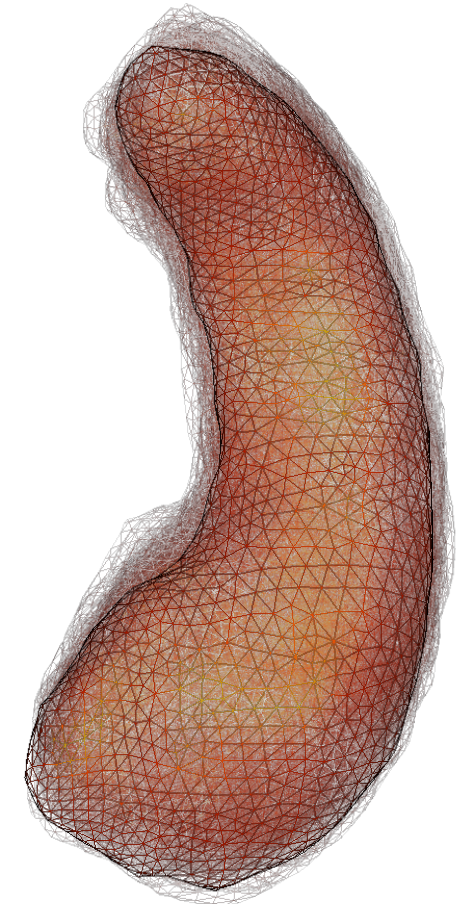
# Shape analysis: GroupWise study

Analysis 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**



Example:  
Barycentre of 95 surfaces

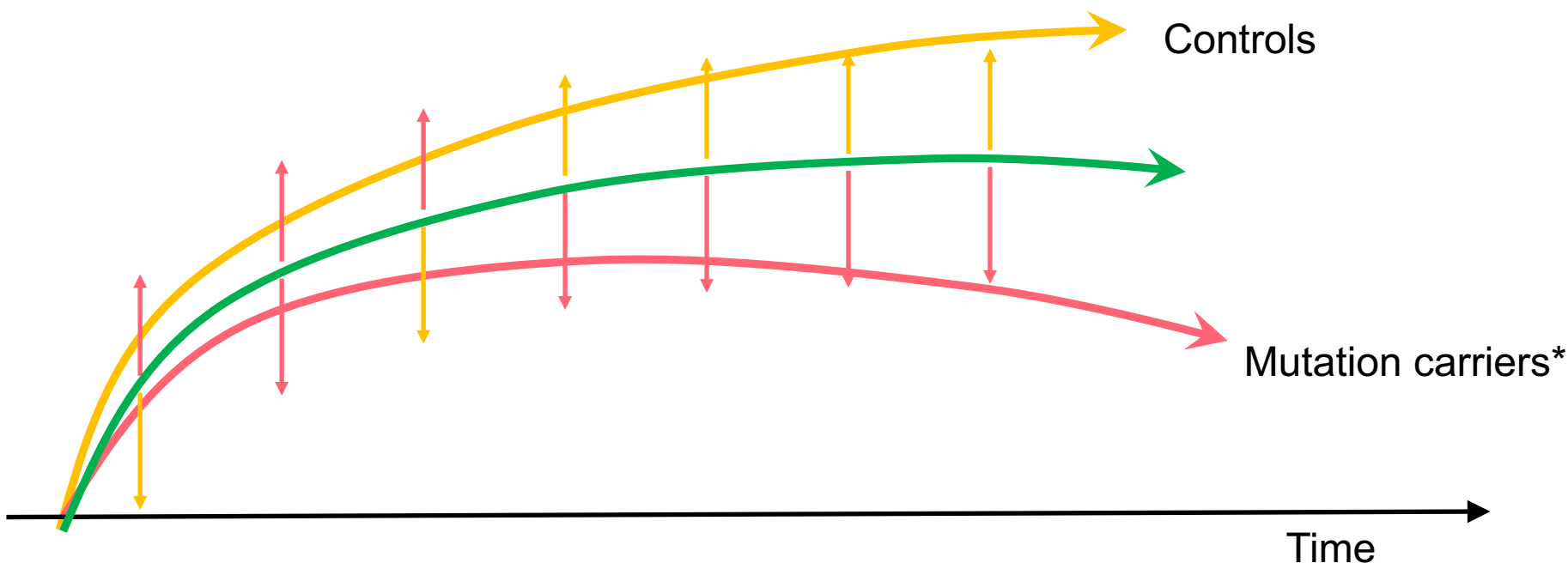
# Shape analysis: Spatio-temporal study

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.



# 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<sup>2</sup>  
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

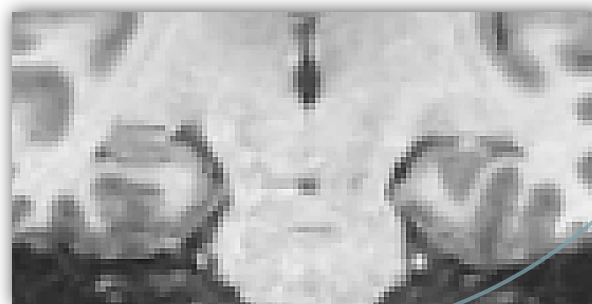
PCs (captured var.) \ EYO	-25	-20	-15	-10	-5	0	+5	+10
PC 1 (20.4%)	0.70	0.94	0.60	0.16	8e-3	<1e-3	<1e-3	<1e-3
PC 2 (11.3%)	0.42	0.26	0.16	0.08	0.03	0.01	0.01	0.03
PC 3 (10.8%)	0.29	0.13	0.08	0.06	0.06	0.08	0.25	0.62
PC 1+2 (31.7%)	0.78	0.80	0.77	0.45	0.07	1e-3	<1e-3	<1e-3
PC 1+2+3 (42.5%)	0.76	0.49	0.23	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

# 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**

Great **potential** of **shape analysis** to better understand brain anatomy

- Analysing different brain structures together (hippocampus and sulci)
- Understanding the sulci's opening

**Shape analysis** Interesting in **longitudinal** studies and for **developmental** studies.

- Follow changes of some biomarker of lesions shape