# A 3D Brain Imaging Study on Effects of Chronic Sensorimotor on the Structure of a Mature Human Cerebral Cortex


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## Abstract


- The purpose of this study is to gain better insight into how amputation affects the human cerebral cortex. Previous studies have revolved around how congenital deformities have affected the brain; however, we tackle the question of how amputation during adulthood changes the structure of the cerebral cortex. In the process, we contribute to the discussion surrounding biological determinism- the way one thing is primarily determined by genetics; hand amputation is an extreme example of how traumatic life experiences can shape brain development, as it involves significant loss of sensory input to, and motor output from, the brain.

- The post-central gyrus has been linked to hand movement. It thus follows that the activity level of the post-central gyrus as captured in high-resolution magnetic resonance images would be distinct between that of an amputee and a non-amputee. Through the use of applied mathematics and development of a quantitative model investigating these differences, we can further our basic understanding of brain mechanisms, which may potentially change the way we view and treat neurological injuries.


## Methods

- We developed our own algorithm/software for 3D brain imaging analysis.
- The software can automatically conduct 3D shape analysis for 3D brain structures, brain cortical surfaces, etc, and detect very subtle shape difference that are otherwise very hard to detect using other existing methods.
- The computational algorithm is based on discrete surface Ricci flow, which is equivalent to a convex optimization problem, therefore has high numerically stability.
- We have applied our method for 3D brain imaging analysis of children with autism [2].
- In this project, we applied the method to study the changes on the structure of the human cerebral cortex between adult amputees and healthy control groups [1].

## Results

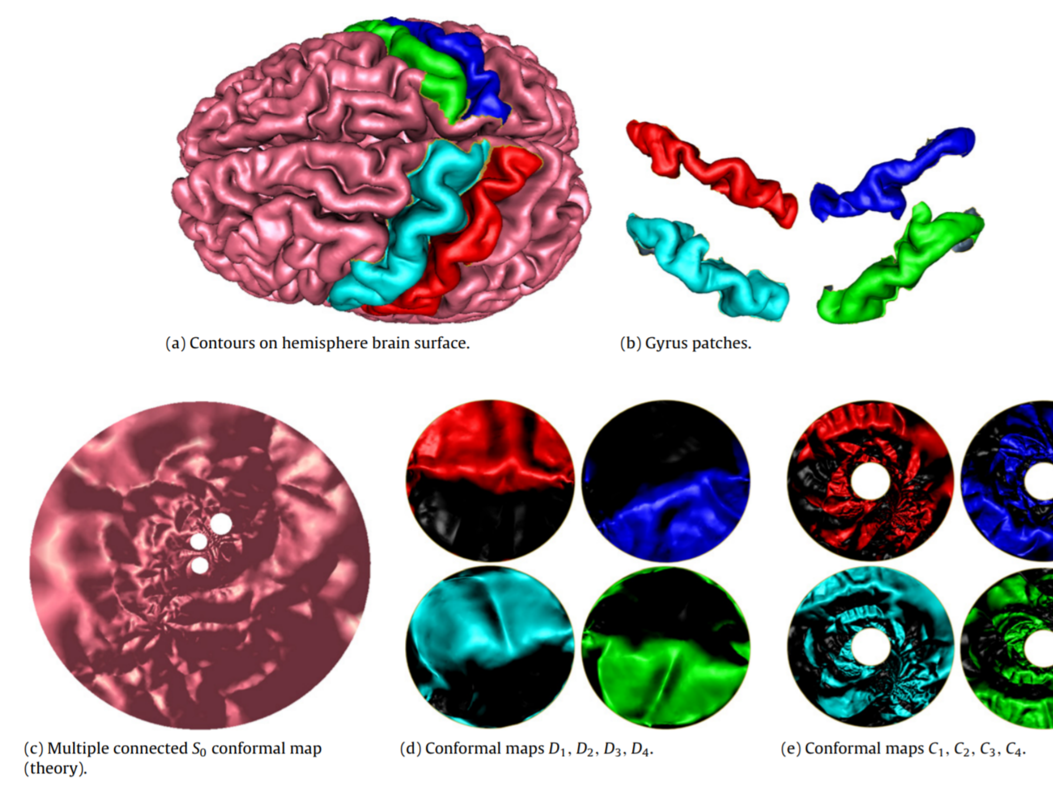



Fig 1: Diffeomorphism signature via uniformization mapping for genus zero surfaces (left and right half of the brain) with 4 simple closed contours γ1, γ2, γ3, γ4 in (a), which correspond to the boundaries c1, c2, c3, c4 of the circle domains D1, D2, D3, D4. These four contours are also mapped to the boundaries of the base circle domain D0 in (a).

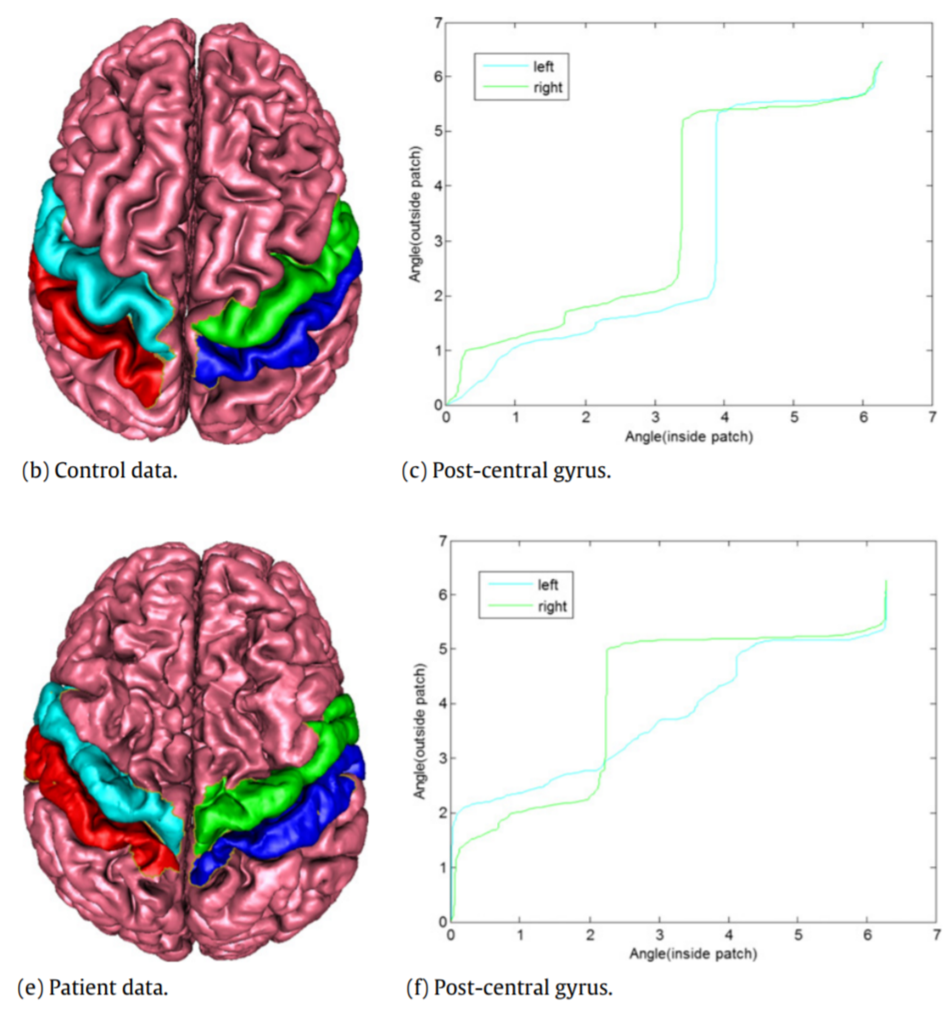
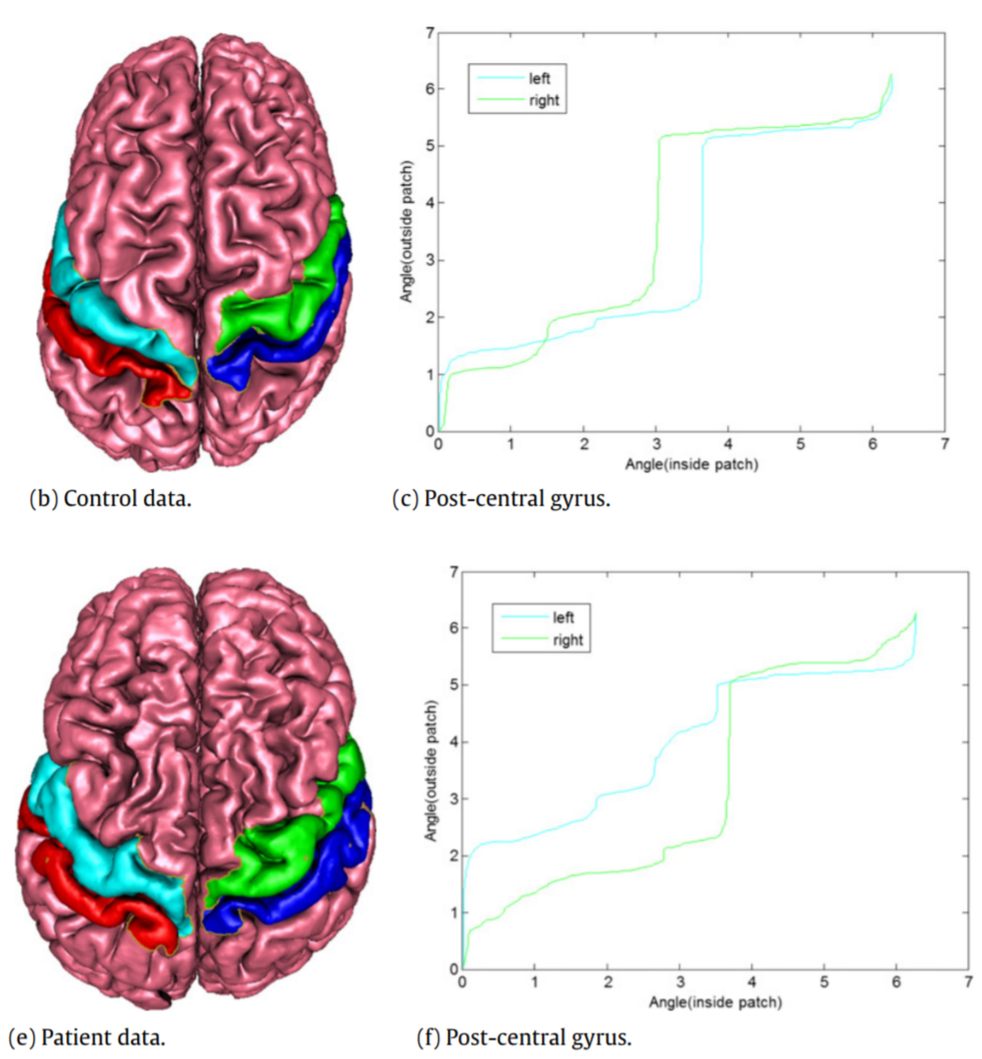



Fig 2: Diffeomorphism signatures of a subject with amputation and a healthy control brain cortex. Each (left and right) half brain is a genus zero surface with 2 contours. The post-central gyrus functional area is a surface patch with one contour.. The figure illustrates the different impacts of amputation to different functional areas. In this group, amputated adult subjects make greater signature difference on post-central gyrus.




## Results (Continued)

Fig 3: Diffeomorphism signatures of a subject with amputation and a healthy control brain cortex. In this group, subject with amputation gives greater signature difference on post-central gyrus.

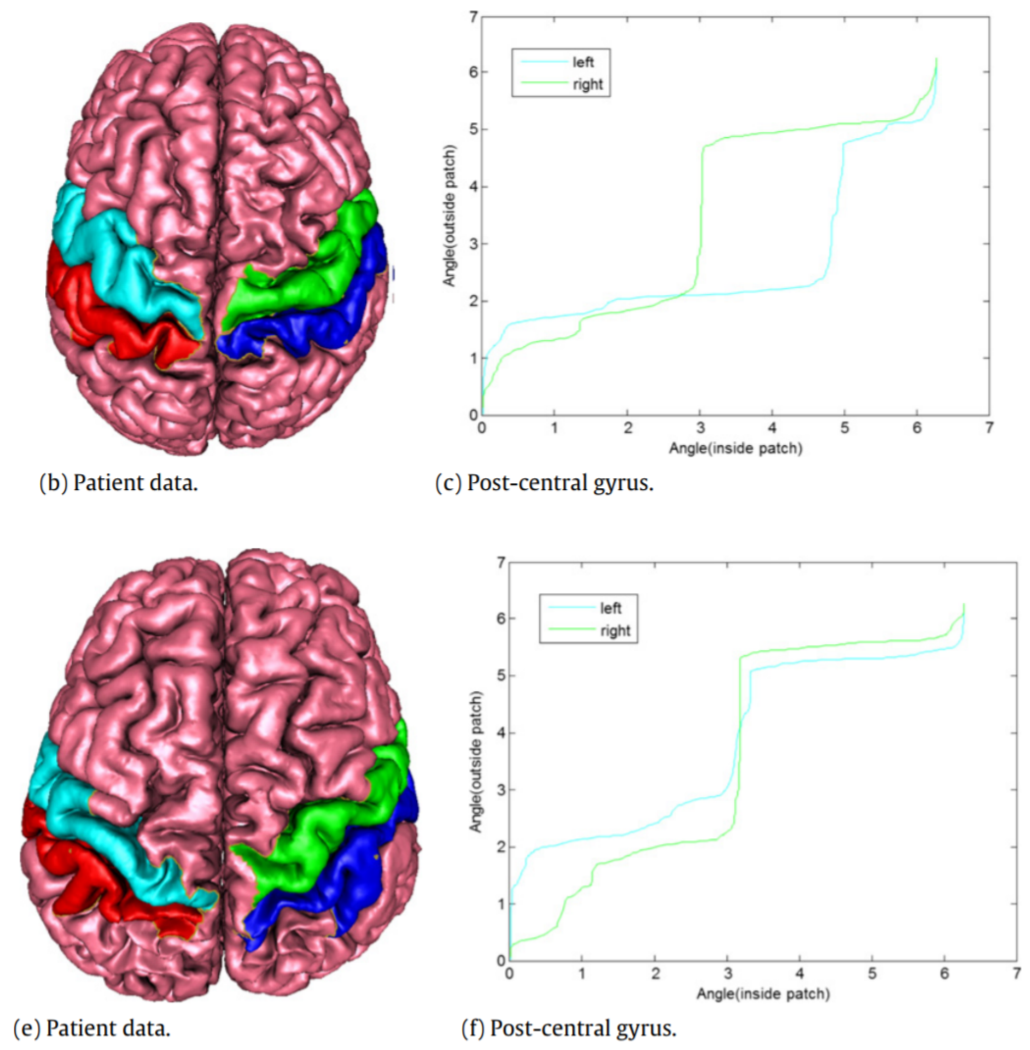



Fig 4: Diffeomorphism signatures of two amputated subjects brain cortex. The figure illustrates the unstableness of an adult amputated subject signatures for post-central gyrus functional areas.

## Conclusion

In this presentation, we propose our in-house algorithm/software that computes the global shape statistical analysis on specified functional areas on brain cortical surfaces based on newly developed technique in applied mathematics and computation to quantitatively analyze the complex topology of the cerebral cortex as captured in high-resolution magnetic resonance images. The computational algorithm is based on discrete surface Ricci flow, which has theoretic guarantees for the existence and uniqueness of the solutions. Discrete Ricci flow is equivalent to a convex optimization problem, therefore has high numerically stability. We applied the method to study the changes on the structure of the human cerebral cortex between adult amputees and healthy control groups. Currently, the method is implemented to allow researchers to create robust two-dimensional surface renderings of individuals' cortical surfaces, which allow highly accurate inter-subject registration and analyses of cortical folding sets of data from recruited patients and healthy controls but it has the potential to extend to a greater number of subjects. The statistical comparison from the preliminary result indicates the impacts of amputations on brain structure.

## References/Acknowledgments


[1] Hao Peng, Xu Wang, Ye Duan, Scott Frey, and Xiangfeng Gu. "Brain morphometry on congenital hand deformities based on Teichmuller space theory." Computer-Aided Design 58 (2015) 84-91.

[2] Qing He, Ye Duan, Kevin Karsch, Judith Miles, "Detecting corpus callosum abnormalities in autism based on anatomical landmarks", Psychiatry Research: Neuroimaging 183 (2010), pages 126–132.