Effect of Family Income on Hippocampus Growth: Longitudinal Study

Abstract No:
2697

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Introduction:

A growing corpus of animal research finds specific morphometry changes in hippocampal subregions after stress [9,10]. In humans, there are few studies that relate the over all reduction in hippocampus volume to stress and affective disorder. The severity of stress level in children has been found to negatively correlate with the change in right hippocampus volume, when assessed longitudinally [2]. Bipolar patients have significant smaller right hippocampus volume compared to normal controls [6]. So far no research in humans has been able to determine if the volume difference is diffuse over the whole hippocampus or localized within small regions of hippocampus in these studies.

We propose a new computational framework for quantifying localized hippocampus growth and able to overcome the limitation of the previous studies. We applied our method in determining the effect of family income on the growth of hippocampus in children.

Methods:

Data and preprocessing:
MRIs were collected using a 3T GE SIGNA scanner on 124 children and adolescents at 11.6±3.7 years from high- (>75000$; n=86) and low-income (<35000$, n=38) parents. The second scans were acquired for 82 of these subjects (n=66 >75000$; n=16 <35000$) at 14±3.9 years. Fig.3 shows the age distribution of the subjects in months. The symmetric diffeomorphic image normalization was performed on MRI [1]. The left and right hippocampi were manually segmented using the protocol outlined in [11]. On the template surface, we have displacement vector field of mapping from the template to individual subject (Fig.1). The length of the displacement measures the amount of growth from the template. Since it is a noisy

measurement, surface-based smoothing is necessary.

Heat kernel smoothing:
The eigenfunctions ψ_j of the Laplace-Beltrami operator Δ on the hippocampus surface is given by solving $\Delta\psi_j = \lambda_j\psi_j$ [5,8]. Heat kernel smoothing of measurement f(p) is performed by the convolution:

$$K*f(p) = \sum \exp(-\lambda_j\sigma) f_j \psi_j(p),$$

where $f_j = \int f\psi_j dq$. Fig. 1 shows the result of heat kernel smoothing with bandwidth $\sigma = 0.5$. Fig.2 shows the first 4 eigenfunctions and how they were combined to give smoothing.

Figure 1

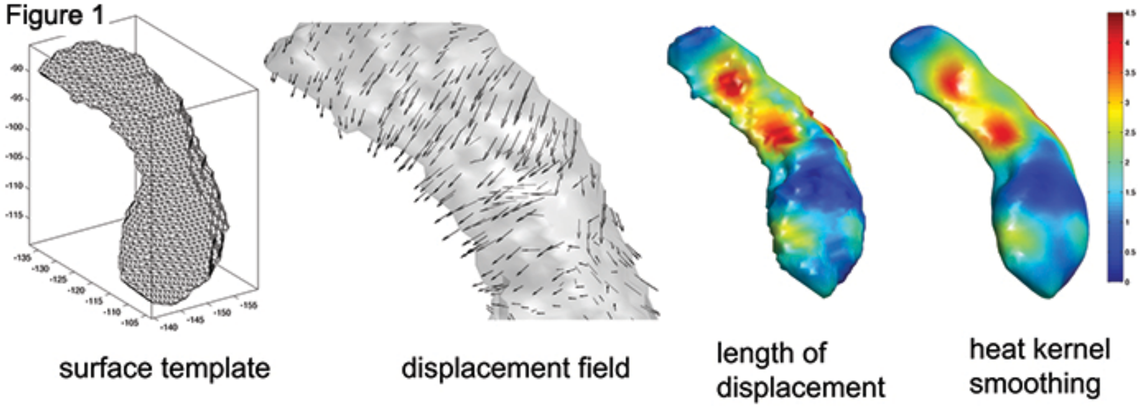
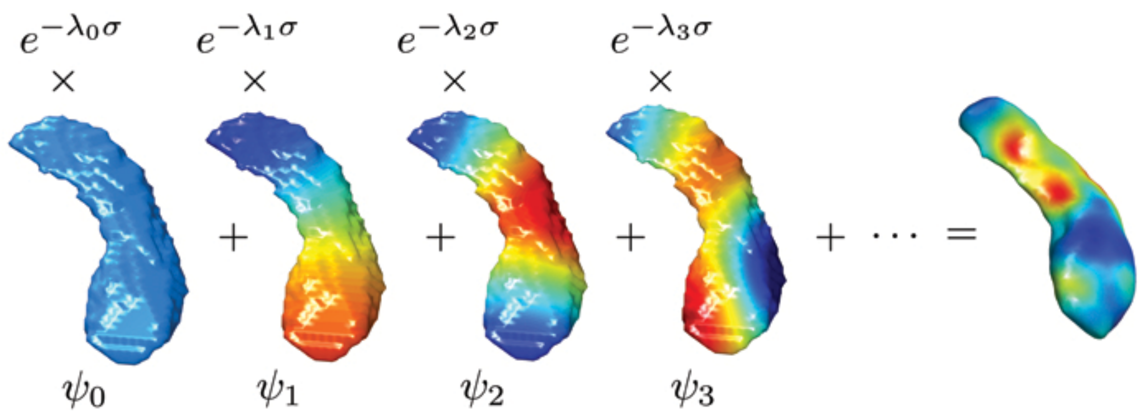


Figure 2

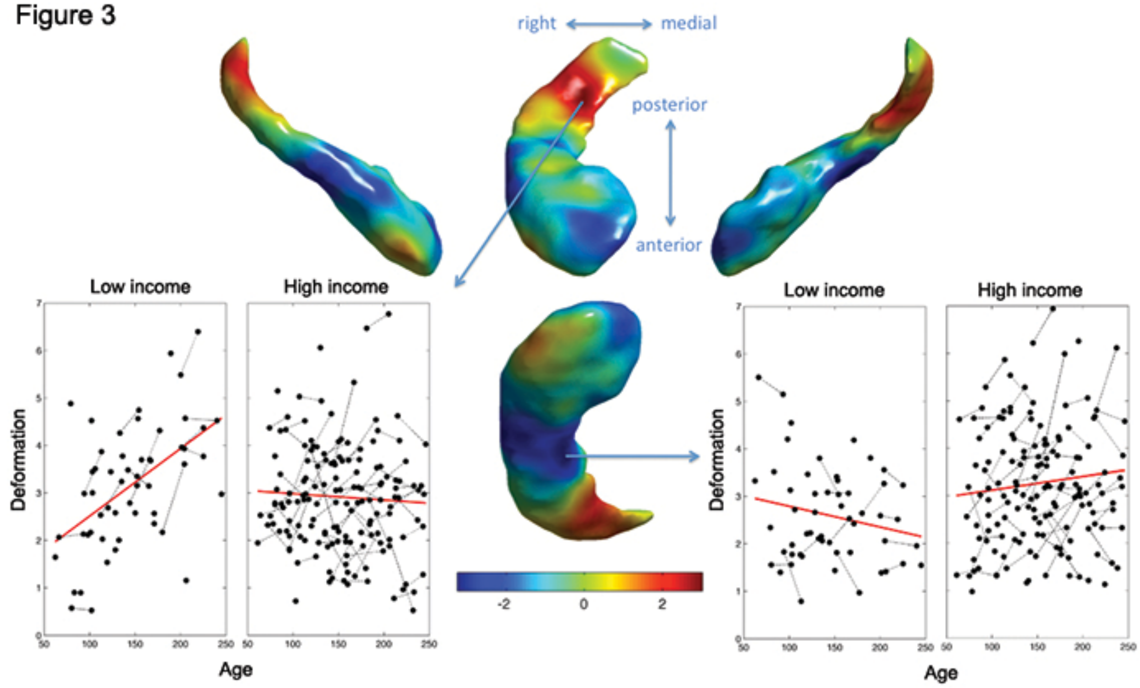


Mixed effect model:
Since 82 subjects have the second scans, we need to explicitly model the within-subject variability that is smaller than the between-subject variability. For each scan, we have the mixed effect model with fixed effect (age, group) and a random effect (subject) terms:

$$\text{deformation} = \beta_0 + \beta_1 \text{ age} + \beta_2 \text{ group} + \beta_3 \text{ age} \cdot \text{group} + \gamma \text{ subject} + \varepsilon,$$

where ε and γ are Gaussian noise. The covariance of γ and ε are expected to have block structures such that there is no correlation among the scans of different subjects. The parameters are estimated via the restricted maximum likelihood method [4].

Figure 3



Results:

We did not detect any statistically significant group difference at 0.01 level in the both left and right hippocampi. However, we obtained highly focalized regions of group difference in growth rate (interaction term) in the right hippocampus (corrected pvalue=0.03). The posterior region is enlarging while the midbody and the anterior parts are shrinking in children from low-income families (Fig.3). This pattern of development is the opposite for children from high-income families.

Discussion:

This is the first study localizing the regions of hippocampus growth difference in children from high- and low- income families. Children from low-income families were found to exhibit poor performance on memory tasks [12]. The anterior portions of the hippocampus have been implicated in relational memory [13]. The right hippocampus is also involved in the active maintenance of associations with spatial information [7]. Future studies investigating the relation between family socioeconomic status and spatial and relational information processing measures are warranted.

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