Morphometric MRI Study of Hippocampal Shape in MCI using Spherical Harmonics

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Learning objectives: Find hippocampal shape changes in MCI

Background: Mild cognitive impairment (MCI) is characterized by memory complaints and impairment in the absence of dementia and confers a high risk for AD. Identifying medial temporal morphological abnormalities, in circuits required for learning and memory, may be critical for early diagnosis and treatment of MCI and AD.

Objective: Volumetric analysis can identify hippocampal atrophy in MCI, but does not localize the structural changes. Shape analysis has the potential to provide important information beyond volume and may localize regionally specific structural changes in the absence of volume differences. This study performed hippocampal shape analysis aiming at a global and local quantitative representation of shape changes in MCI.

Methods: Participants were 40 adults with amnestic MCI (age 72.5 ± 3.3), 40 adults with cognitive complaints (CC) but no impairment (72.6 ± 2.6), and 42 normal controls (CN) (70.8 ± 2.6). MRI data were a T1-weighted SPGR coronal series acquired on a GE 1.5T LX magnet. The hippocampi were segmented using BRAINS software. The left and right hippocampi were treated as a single shape configuration. The spherical harmonics (SPHARM) description was used for surface modeling, with the parameter space being aligned according to the first order ellipsoid for surface correspondence. After normalizing for the total volume, landmarks were created by uniform surface sampling (Figure 1(a,b)) and aligned by a quaternion-based algorithm. For each landmark, the local shape change was defined as the distance between an individual and the mean along the normal direction of the mean surface. Surface signals were modeled as Gaussian random fields. Heat kernel smoothing was employed to increase SNR on the hippocampal surface (Figure 1(c)) and statistical inference was performed via random fields theory.

Conclusions: The results of group analyses (t-maps in Figure 2) show that statistically significant regions of shape changes only appear between CN and MCI. The CC group showed a more intermediate pattern. The structural changes in MCI were primarily located in the anterior right hippocampus and posterior left hippocampus (Figure 3). Shape analysis has the potential to inform early detection and is likely to be useful for longitudinal monitoring of response to therapeutic agents.

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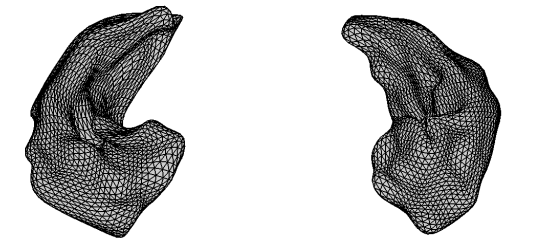
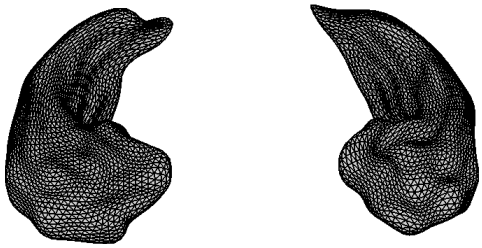


(a) Subject 1



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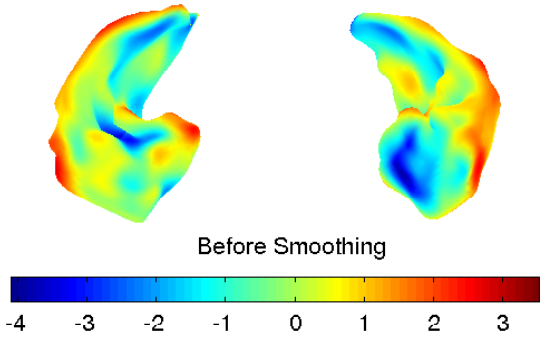
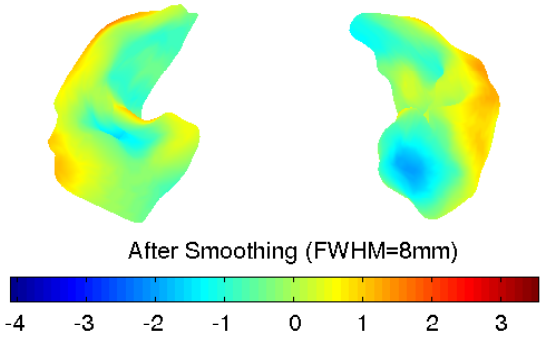
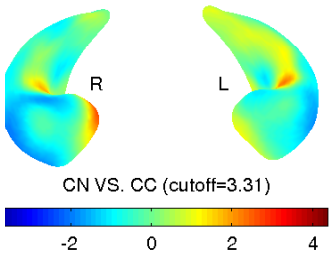
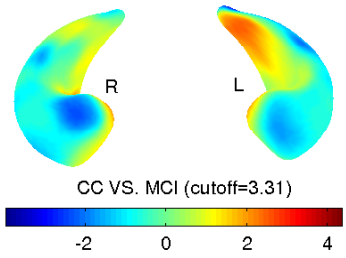




(c) Heat kernel smoothing

Figure 1: (a-b) Landmark representation for hippocampal shapes: mesh vertices are landmarks. (c) Heat kernel smoothing result: on the left, the initial signal is mapped on to the surface; on the right, the signal is smoothed using a heat kernel of FWHM $= 8$ mm. Our scaling scheme makes the mean shape have a total volume of $6780\,\mathrm{mm}^3$.





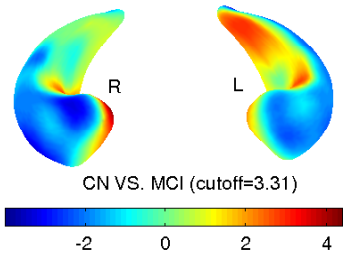


Figure 2: t-maps of group analyses for CN versus CC (left), CC versus MCI (middle), and CN versus MCI (right), where FWHM $= 8$ mm is used for heat kernel smoothing. Positive/negative t-values indicate that outward/inward directions change the mean to shapes of the first class. Regions of statistically significant shape changes only appear between CN and MCI.

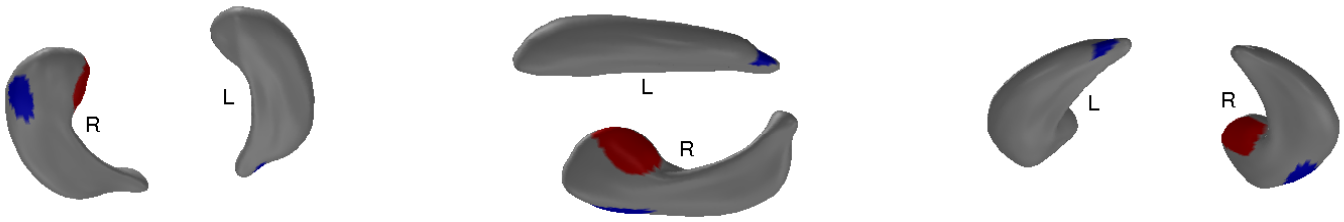


Figure 3: Regions of statistically significant structural changes between CN and MCI, which were created by thresholding the t-map using the cutoff value 3.31 (corrected for 95% confidence level). Three different views are displayed. Red/blue colors indicate that outward/inward directions change the mean to CN. Structural changes are located mostly at the anterior part of the right hippocampus and also at the posterior part of the left hippocampus.