Visual Analysis of Brain/Gait Correlations

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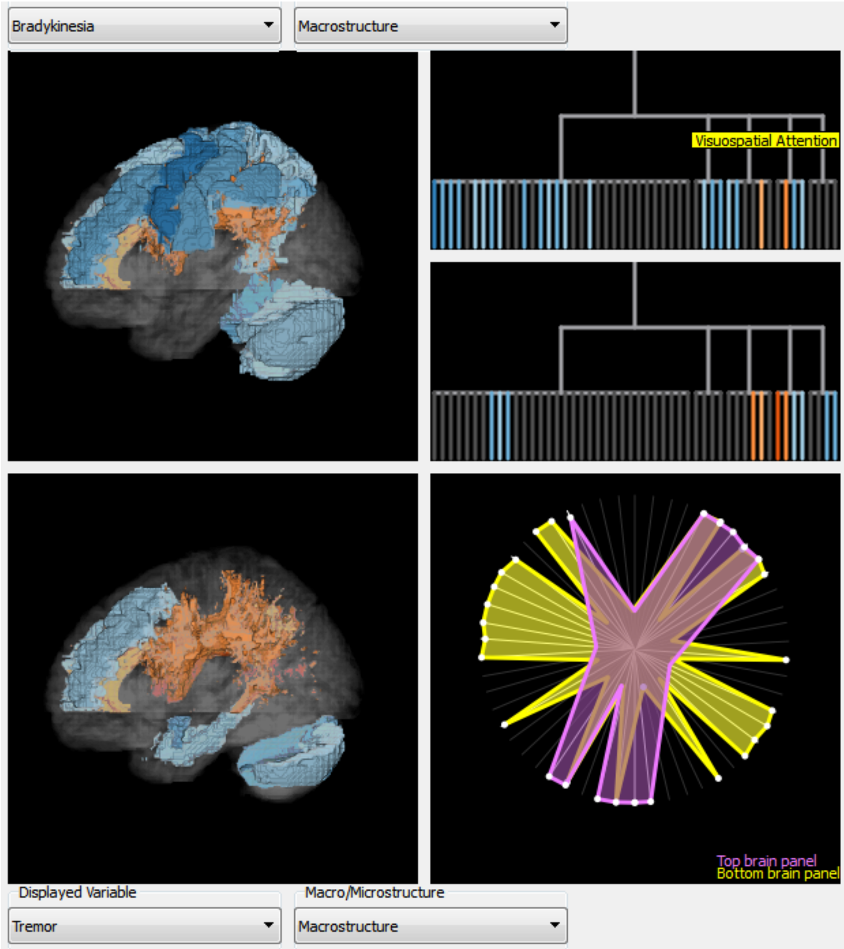

Figure 1: Gait Visual Analysis. In this scenario, the user starts by selecting two gait variables to compare, bradykinesia and tremor. The star plot shows the overlap between variables. The top and bottom left brain volume renderings help detect spatial patterns. Finally, the dendrograms (top right) give information about the functional structure of the brain. In this example, the user can easily see how the regions associated with visuospatial attention correlate with both bradykinesia and tremor.

1 Introduction

Epidemiologists study the relationship between neurological aging and mobility impairment in "normal" older individuals. They have found out that balance difficulty and slow gait can indicate brain structural and functional abnormalities which, for example, can be used to predict a greater risk for dementia [4]. Studying the relationship between brain and gait can help researchers identify structural changes in the brain that are associated with neurological aging. These structural changes can then be targeted for interventions that can prevent the loss of independence that occurs as physical mobility declines in elderly individuals.

Typical analyses are performed on a region-by-region basis because of the difficulty of establishing voxel-by-voxel correspondence between brain images of elderly people and a standard brain template. Furthermore, investigating the functional structure of the brain, such as relationships between the brain and different activities, introduces the added problem, from a visualization point of view, of integrating the spatial data inherent in the structure of the brain and the non-spatial data resulting from functional relation-

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ships. To explore this space, we present a novel visualization application which enables the users to perform visual comparative region of interest (ROI) analysis in the presence of uncertainty. It facilitates the exploration of spatial/non-spatial relationships in a multidimensional space spanning both spatial and non-spatial information. We demonstrate the analysis tool on a dataset which investigates the relationship between brain regions and gait and provide preliminary feedback.

2 Data Analysis

The dataset for this project studies the relationship between brain and gait in community-dwelling older adults [5]. The gait data consists of three variables: bradykinesia, gait disturbance and tremor. Bradykinesia is a measure of slow or hesitant motion during activities such as heel tapping. Gait disturbance is a measure of abnormality in gait (e.g., small amplitude or poverty of movement in general), posture etc. Tremor is rated as present if detected, for example, either at rest or during action in either foot. The brain data is an assessment of the macro- and micro-structure of the brain. The macro-structure was measured as volume of gray matter and of white matter tracts hyperintensities (lesions in white matter). Diffusion Tensor MRI was used to quantify the micro-structure of normal appearing gray (mean diffusivity) and white matter (fractional anisotropy).

The ROIs were based on the Automated Anatomical Labeling atlas [6], which takes into account the functional structure of the brain when breaking it up into different regions. In the analysis, the ROIs were grouped based on the function they perform, classification reflected in the visualization in the dendrogram in the top right corner in Figure 1. Finally, the brain/gait correlations were computed using iterated Tikhonov regularization [2] using the L-curve method to determine the regularization parameter. Since there are three gait variables and two types of brain measurements, there are a total of six correlation values for each region.

3 Methods

From our discussions with the domain experts, we have identified the following list of tasks they would like to carry out: 1) compare correlations of microstructure to correlations of macrostructure for the same gait variable; 2) compare correlations of subgroups of regions, according to the functions they perform; 3) visually see spatial patterns for gait variables that vary in the same way; 4) compare correlations of one gait variable to correlations of another gait variable.

Given that three of the four tasks focus on comparing different correlations, we designed a visualization application in which the emphasis was placed on enabling the user to make side-by-side visual comparisons. The application consists of 4 linked views: 2 interactive volume rendering panels, a dendrogram [3] and a star plot [1]. Details on demand are used to show the names and significance levels of the regions.

Two volume rendering panels facilitate the analysis of brain/gait spatial patterns (Figure 1). The correlations are color-mapped according to their significance/uncertainty levels. To clearly distinguish between two types of brain structures, we used different hues, blue for white matter and orange for white matter. Saturation is varied according to significance levels; darker shades of blue indicate higher correlations. Dynamic queries are employed to enable the user to filter the correlations to the desired significance level; the filtered-out regions are displayed as transparent images to maintain context. The volume rendering panels facilitate tasks 1 and 3.

The star plot view displays an overview of the correlations between brain and gait using the brain measurements, gait variables and significance levels selected by the user. The star plot axes correspond to brain regions and the value mapped to each axis represents the significance level. The higher the significance level, the farther from the center the point is mapped. Linking and brushing is used to gray out the axes (which represent brain regions) and remove the significance level mapping for the regions not displayed in the two volume rendering panels. In conjunction with the volume renderings, the star plot facilitates task 4.

Finally, the dendrograms enable the user to compare different groups of regions (task 2). Each of the trees is linked to the corresponding volume rendering view. The leaves represent individual regions while their parents correspond to groups of regions associated with particular functions. For example, some regions are involved in mobility, others in visuospatial attention and yet others in motor imagery. Figure 1 shows that the regions associated with visuospatial attention are more highly correlated with bradykinesia than with tremor.

4 Results and Evaluation

We conducted an informal evaluation with three domain experts in the department of Epidemiology at the University of Pittsburgh. The expert users were particularly excited about the ability to compare and analyze spatial and non-spatial information. The epidemiology expert lead has adopted the tool for research purposes. The positive feedback focused on the interactions with the two volume-rendered images of the brain and on the star plot. They thought the visual abstractions were very intuitive to use for displaying brain data and formed several hypotheses to further explore the dataset. For example, they will next examine the mean percentage difference between subjects who had one of the conditions listed as gait variables (such as tremor, for example) and the subjects who did not.

5 Conclusion

We presented a novel analysis tool that can be used for the visualization of correlations between brain and gait measurements. Through our approach of allowing the user to explore relationships that span both spatial and non-spatial information, we investigate an under-explored area by the visualization community. Expert evaluation indicated that visual abstraction can be very intuitive to use in this type of analysis. Our application has the potential to be very useful to researchers who study aging.

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