Deterioration of Abstract Reasoning Ability in MCI and Alzheimer's Disease: Correlation with Local Gray Matter Volume Loss using DARTEL VBM Analysis

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Introduction

Raven's colored progressive matrices (CPM) are psychological tests for assessment of abstract reasoning developed by JC Raven in 1947. The examinee is asked to choose the missing segment of the test item required to complete a larger graphical pattern. The test is of widespread international use because of its ease of use and non-verbal nature. For the same reasons, CPM is considered to be especially useful in evaluating children and the elderly, and is sometimes incorporated into the screening test for dementia. In spite of its popularity, there is no published data on which brain regions are related to deterioration in performance of this test in the context of dementia. We aimed to answer this question by mapping brain regions where local gray matter (GM) loss is correlated with deterioration the performance of CPM in patients with Alzheimer's disease (AD) and mild cognitive impairment (MCI).

Materials and Methods

We analyzed MR data of a total of 37 consecutive patients including 19AD patients (M/F=6/13, mean age=74.3±7.2 years) and 18 MCI patients (M/F=3/15, mean age=75.4±5.9 years). All AD and MCI cases were carefully diagnosed by the case conferences by both experienced neurologists and psychiatrists. All patients received both CPM and Mini-mental state examination (MMSE).

Images were obtained using a 3.0 T MR imager (Achieva Quasar Dual, Philips) and an 8-channel head array receiving coil. For each patient, high-resolution T1-weighted MR images were obtained using a 3D gradient-echo sequence at the following parameters: TR/TE/TI = 8.3ms/3.8ms/240ms, flip angle = 8 degrees, SENSE factor = 2, NSA = 1, FOV = 240 mm, matrix size = 240x240, slice thickness = 1 mm. Images were analyzed according to the regimens of voxel-based morphometry (VBM) on SPM8 software. During the VBM analysis, non-linear registration was performed based on an algorithm called Diffeomorphic Anatomical Registration using Exponentiated Lie algebra (DARTEL). The size (FWHM) of a Gaussian kernel for smoothing was 8 mm.

Correlation between the scores of CPM and MMSE was evaluated using Pearson's correlation coefficient. A multiple regression analysis was used to map the brain regions where GM volumes were correlated with total scores of CPM and MMSE, respectively, while controlling the effects of age, sex of the patients as well as clinical diagnosis (MCI or AD). The voxel-level significance threshold was set at $p < 0.001$ (uncorrected for multiple comparisons).

Results

The total scores of CPM of all patients ranged from 8 to 35 (mean±SD = 25.2±5.9) and those of MMSE scores ranged from 15 to 29 (mean±SD = 24.1±4.0). A significant correlation was found between the CPM scores and MMSE scores ($r = 0.71$, $p < 0.0001$). **Figure** below shows the rendered maps of brain regions where local GM volumes were positively correlated with CPM scores. It also shows regions with significant positive correlation with MMSE scores. The strongest correlation with CPM scores was seen in the left middle frontal gyrus while a region with the largest volume was identified in the left superior temporal gyrus. Correlations were seen in 12 additional regions including bilateral frontal, parietal and temporal lobes, right occipital lobe and right cerebellum. At the same statistical threshold, correlation mapping for MMSE resulted in detection of fewer regions only in the bilateral parietal lobes.
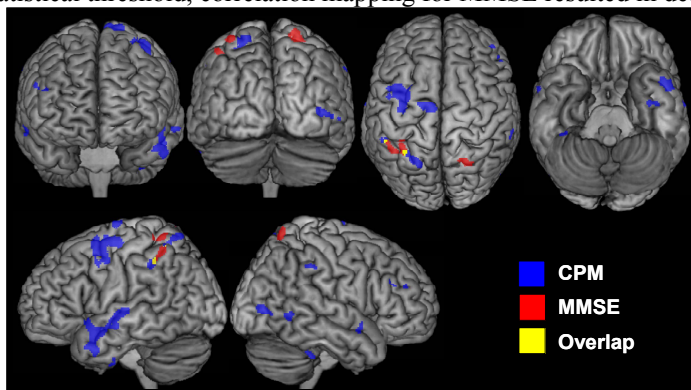
Figure: Mapping of brain regions where local GM volume was significantly positively correlated with CPM scores (blue) and with MMSE scores (red). Their overlaps are colored yellow. Voxel-level significance threshold is $p < 0.001$ (uncorrected for multiple comparisons). The extent threshold is 50 voxels.

Discussion

We revealed that deterioration of abstract reasoning ability measured by CPM in MCI and AD patients were correlated with local GM loss in multiple regions in the brain, which partly agreed with the results of previous activation studies (references 1and 2). We also revealed that, in spite of a close correlation between behavioral results of CPM and MMSE, relevant cortical regions for the two tests were very different.

References

1. Prabhakaran V, et al. Cogn Psychol 1997;33(1):43-63.   2. Soulieres I, et al Hum Brain Mapp, in press.