# Structural and functional changes of hippocampus in Long Life Experienced Taxi Driver

Geon-Ho Jahng[1], Kyung-Mi Lee[2], Myung-Won You[2], Eo-Jin Hwang[3], Min-Ji Kim[3], Hyug-Gi Kim[4], Dong-Kyun Lee[5], Jong-Min Lee[5], Chang-Woo Ryu[1], Wook Jin[1], Dal-Mo Yang[1], and Ji Seon Park[6]

*[1]Radiology, Kyung Hee University Hospital at Gangdong, Kyung Hee University, Seoul, Seoul, Korea, [2]Radiology, Graduate College of of Medicine, Kyung Hee University, Seoul, Seoul, Korea, [3]Radiology, Kyung Hee University Hospital at Gangdong, Seoul, Seoul, Korea, [4]Biomedical Engineering, Graduate College of Electronics and Information, Kyung Hee University, Youngin, Gyeonggi-do, Korea, [5]Biomedical Engineering, Hanyang University, Seoul, Seoul, Korea, [6]Radiology, Kyung Hee University Hospital, Kyung Hee University, Seoul, Seoul, Korea*

**Introduction:** Hippocampus has been the main subject of many studies on human memory functions. The structural or functional changes in the hippocampus in relation to long-term navigation have been investigated by some scientists (Slotnick SD. 2010). There was no study that investigated VBM, shape analysis, and BOLD functional changes together in the taxi driver group compared with a normal control group. The aims of this study were to compare: 1) changes in hippocampal volumes using automatic segmentations of the hippocampi, 2) alterations of the hippocampal shapes using shape analysis, and 3) functional changes in the temporal lobes using BOLD fMRI, between the two groups. Therefore, we attempted to analyze the differences in hippocampal shape and volume using 3D T1WI and the different neural activities using BOLD fMRI between the very well experienced taxi drivers and control subjects from Korean population.

**Materials and Methods:** Data was reported from 4 male subjects who had 20 - 30 experience as taxi drivers and did not use a navigation tool or used only for a few years while driving and 4 male age-matched healthy control subjects who used a navigation system while driving in the same area of Pusan, South Korea. The mean age in the control group was 50 years (range, 49~53 years) and that in the taxi driver group was 51 years (range, 46~59 years). For BOLD fMRI, we had a session of block design. There were four blocks for stimulations and four blocks for baseline controls. Fifteen dynamics were obtained in each 45-second block. There were a total 120 dynamics. During the activation period, there were four problems showing roadmaps to find a final destination by imagining real driving on the road. In each problem, there was a starting point, a stop by point and a final destination point. The overall picture, including the starting point, stop by point and final destination point was shown for the first 3 seconds. The experiment was performed using a 3T MRI system with a dedicated 8-channel head coil (Achieva, Philips Medical Systems, Best, Netherlands). In order to investigate the hippocampal shape and volume, a three-dimensional T1-weighted (3D T1W) sagittal sequence was run for 5 min with the resolution = 1 ×1 × 1 mm. To investigate the functional differences between the two groups, the BOLD fMRI data were acquired using a gradient-echo echo-planar imaging (EPI) sequence using the fMRI paradigm mentioned in the previous paragraph.

*Hippocampal volume:* The 3D T1WI image in native space was registered to the Montreal Neurological Institute (MNI) template using non-linear registration. The tissue classification into the gray matter, white matter and cerebrospinal fluid (CSF) was performed on the registered 3D T1WI image. After that, the hippocampus in individual brain was segmented using automatically defined hippocampus on the MNI brain template (Firbank MJ, et al. 2008).

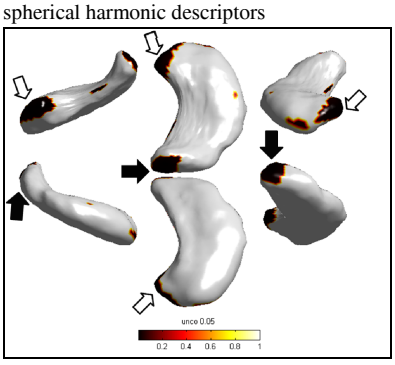
*Hippocampal shape analyses:* For hippocampal shape modeling, the in-house software was used. Details have been described in the previous publication (Lee JM, 2004). The main steps were as follows: The region of interest (ROI) was automatically delineated using the center of mass of hippocampal volume. A 3D hippocampal model was generated through the deformation of the initial shape model (Chung MK, 2003).

*Roadmap navigation fMRI data analysis:* SPM8 was used. To investigate within-group activation in the second level analysis, one-sample t-test was performed for each group using the result of the individual level analysis. The voxel-wise significance threshold of $p = 0.01$ was used for correcting for multiple comparisons by the false discovery rate (FDR) method.

**Results :**

*Hippocampal volume and shape analyses:* The mean ± SD hippocampal volume normalized to the intracranial volume (ICV) value in the taxi driver group was 0.198 ± 0.005 and 0.198 ± 0.009 for the right and left hippocampus, respectively. The mean ± SD hippocampal volume normalized to the ICV value in the control group was 0.208 ± 0.010 and 0.199 ± 0.016 for the right and left hippocampus, respectively. There were no statistically significant differences in the hippocampal volumes for both sides between the two groups ($p > 0.05$). The head and tail portions of the left hippocampus in the taxi driver group were slightly but statistically significantly larger than those of the left hippocampus in the control group ($p < 0.05$, uncorrected). There was no significant difference in the right hippocampal shape between the taxi driver group and the control group ($p = 0.2$). The normalized mean ± SD distance of the left hippocampus was 12.945 ± 0.198 and 12.891 ± 0.523 in the taxi driver and control groups, respectively. The mean ± SD length of the left hippocampus in the taxi driver group was significantly longer than that of the left hippocampus in the control group ($p < 0.05$, uncorrected). There was no significant difference in the mean length of the right hippocampus between the taxi driver group and the control group.

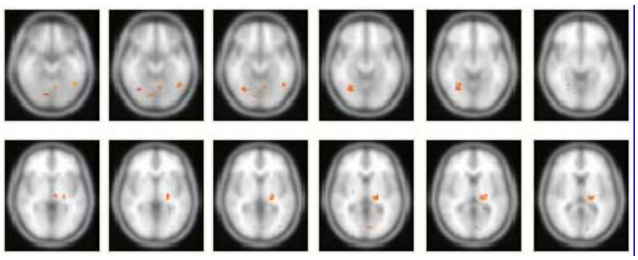
**Fig 1.** The morphometric analysis with reconstructed hippocampal structures using spherical harmonic descriptors




*Roadmap navigation fMRI:* The temporal lobe and the limbic lobe were more activated in the taxi driver group than in the control group. Especially a significant activation in the fusiform gyrus was noted in the taxi driver group. The control group showed more activation in the frontal lobe.

**Discussions:** We were interested in investigating the very well experienced taxi drivers who did not use a navigation system because it is likely that they may have used the temporal lobe functions more frequently than the other drivers who often used a navigation system. This study can be meaningful due to the application of both hippocampal shape and volume in the structural analysis and BOLD functional MRI in the functional analysis for examining the spatial memory tasks, relationship between spatial memory and the temporal areas, and environment-induced changes in the related brain regions. The first major finding of this study was that there was a significant difference in the left hippocampal shape between the taxi driver group and the control group. Examination of the structural changes in the hippocampus on VBM in several previous studies (Maguire EA, 2000) demonstrated that the gray matter volume of the posterior hippocampus was greater in the taxi driver group compared with the non-taxi driver control group. The second major finding of this study was that the fusiform gyrus area showed activation in the taxi driver group but not in the control group. Previous studies showed that fusiform regions should be thought to be critical in encoding face traits and identity (Vuilleumier P and Pourtois G. 2007).

**Fig. 2.** Activated brain regions in the functional MRI study of the taxi driver group



**Conclusion:** The hippocampus in the taxi drivers was more elongated with slightly larger head and tail portions and increased neural activities in the fusiform gyrus. This means that occupational dependence on spatial navigation could lead to functional differentiation within the hippocampus and the related regions as an environment-related plasticity of the brain. In other words, the continuous usage of spatial navigation performance might reduce hippocampal degeneration.

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**References**: Slotnick SD. Neuroimage 2010;49:1769-1776; Firbank MJ, et al. Hum Brain Mapp 2008;29:1442-1449; Lee JM, et al. Neuroimage 2004;22:831-840; Chung MK, et al. Neuroimage 2003;18:198-213; Maguire EA, et al. Proc Natl Acad Sci U S A 2000;97:4398-4403; Vuilleumier P and Pourtois G. Neuropsychologia 2007;45:174-194.