Expertise modulates brain activity during passive driving: a study in professional and naïve drivers

Stand-By Time

Wednesday, June 13, 2012: 1:30 PM - 3:30 PM

Poster No:

862

On Display:

Wednesday, June 13 & Thursday, June 14

Authors:

Giulio Bernardi[1], Emiliano Ricciardi[1,2,3], Giacomo Handjaras[1], Anna Gaglianese[1], Lorenzo Sani[1,2,3], Alessandra Papasogli[4], Riccardo Ceccarelli[1], Ferdinando Franzoni[5], Fabio Galetta[5], Gino Santoro[5], Rainer Goebel[6], Pietro Pietrini[1,2]

Institutions:

[1]Laboratory of Clinical Biochemistry and Molecular Biology, University of Pisa, Pisa, Italy, [2]Department of Laboratory Medicine and Molecular Diagnostics, AOUP, Pisa, Italy, [3]MRI Laboratory, Fondazione Regione Toscana/CNR 'G.Monasterio', Pisa, Italy, [4]Formula Medicine, Viareggio, Italy, [5]Department of Internal Medicine, University of Pisa, Pisa, Italy, [6]Maastricht University, Maastricht, Netherlands

Poster Presenter(s)

Giulio Bernardi - Contact Me
Laboratory of Clinical Biochemistry and Molecular Biology, University of Pisa
Pisa, Italy

Introduction:

Driving is a complex behavior that requires the integration of attentional, perceptual, motor and other cognitive functions. Although many studies have investigated brain activity related to driving simulation in a wide gamut of conditions, including that associated with performance impairment (e.g. alcohol intoxication [1]), little is known about the brain functional correlates of professional competitive driving, that requires greater motor and attentional skills [2, 3]. Here we used fMRI to examine functional brain activity in professional car racers as compared to naïve drivers while they watched a 'camera-car' driving of a Formula One race car. A 'passive driving' task, rather than an active one, was chosen to avoid potential confounds caused by the different skill levels between the two groups.

Methods:

We used fMRI (GE Signa 1.5T) to examine neural activity while 10 professional (24±5 y) and 9 naïve (28±4 y) right-handed healthy drivers watched a continuous 'camera-car' video of a Formula One car racing on four different circuits. Subjects were instructed to imagine themselves driving the car. Individual functional data were preprocessed and registered to the Talairach Atlas [4] coordinate system using AFNI [5]. Then, Inter-Subject Correlation (ISC) was used to define task-related brain regions whose neural activity temporally correlated across participants [6]. Within each group, Pearson's coefficient was computed between every pair of subjects on a voxel by voxel basis, and then averaged. Significant (FDR-corr. $p < 0.001$) correlations were identified using a fully non-parametric voxel-wise permutation test (ISC-toolbox [7]). To assess additional differences between groups, we also computed a Time-Window (TW)-ISC analysis [8], using a procedure similar to that described above, but here calculating correlation coefficients within a defined 'sliding' time-frame (length: 10 TR; step: 1 TR) (FDR-corr. $p < 0.05$). For each group correlation timecourses were then extracted from the ISC-peaks located in motor (M1) and visual (V1) brain areas to look for potential differences between professional and naïve drivers relatively to response properties of these regions.

Results:

In both groups, passive driving significantly modulated regional brain activity in a network of cortical areas involved in driving behavior [9], including bilateral visual cortex, precuneus, cingulate, parahippocampal, superior parietal, medial frontal and right dorsolateral prefrontal cortex, and left precentral area (Fig.1). However, professional drivers recruited additional cortical areas, including ventral and dorsal premotor and inferior parietal regions within the human mirror system [10] (Fig.1-2).

Moreover, during each video-clip, professional drivers showed stronger and more numerous correlation increases in both left and right M1 as compared to naïve drivers, who conversely showed more correlation increases in V1 (Fig.3). Interestingly, in the professional racers correlation peaks in motor areas were temporally located immediately before and/or in correspondence of traits of circuit with the highest attentional demands (e.g. a series of curves).

Conclusions:

These results, in line with our previous findings [2], indicate that the brain functional organization developed by skilled race car drivers differs from that observed in naïve individuals. Interestingly, the different responses observed in visual and motor areas indicate that naïve drivers were characterized by a consistent modulation of brain activity in occipital cortex, while professional drivers presented a higher involvement of motor control devoted areas. In fact, while naïve drivers possess only a basic driving knowledge, professional drivers have been trained specifically in car racing and have the motor competence to effectively cope with the specific situations arising during the Formula One passive driving task. Differently put, naïve individuals simply watched the race, while professional drivers imagined to act.

Learning and Memory:

Skill Learning

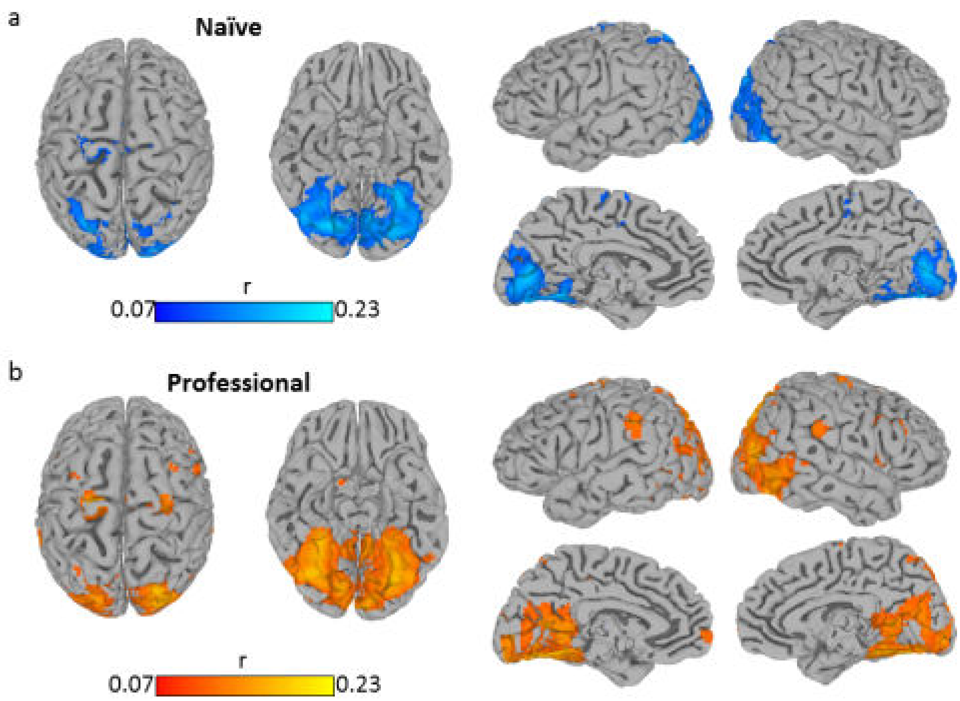

Fig1. Group Inter-Subject Correlation maps obtained by averaging Pearson's correlation coefficient computed between each pair of subjects within the same group at each location. Naïve drivers results (a) are shown in dark/light blue while professional drivers results (b) are shown in red/yellow. All results are FDR corrected $p < 0.001$.

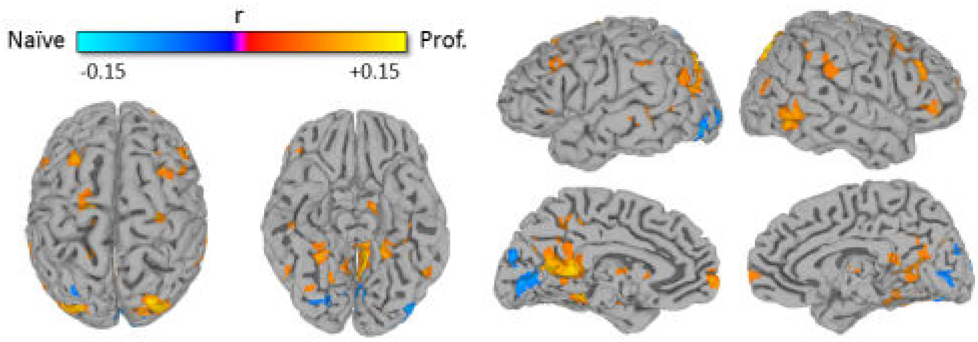

Fig2. Contrast between averaged correlation maps of the two groups; here dark/light blue indicate an higher correlation value in naïve drivers, while red/yellow colors indicate an higher correlation in professional drivers. Fisher's z transformation was applied on correlation coefficients obtained for each pair of subject to improve their normality. Then, averaged group correlation maps were computed, and a 'contrast' map was obtained by calculating the simple mathematical difference between the two group maps on a voxel-by-voxel basis ('professional – naïve'). To determine which of the contrast values were higher than what can be expected by chance, we generated a new 'dummy' contrast dataset applying the procedure described above after shifting BOLD timecourses of each subject and voxel by a random amount. The distribution of all correlation values, including that from 'real' results and that from the 'dummy' contrast map, were used to determine the cut-off that produced a false alarm probability of $p < 0.005$.

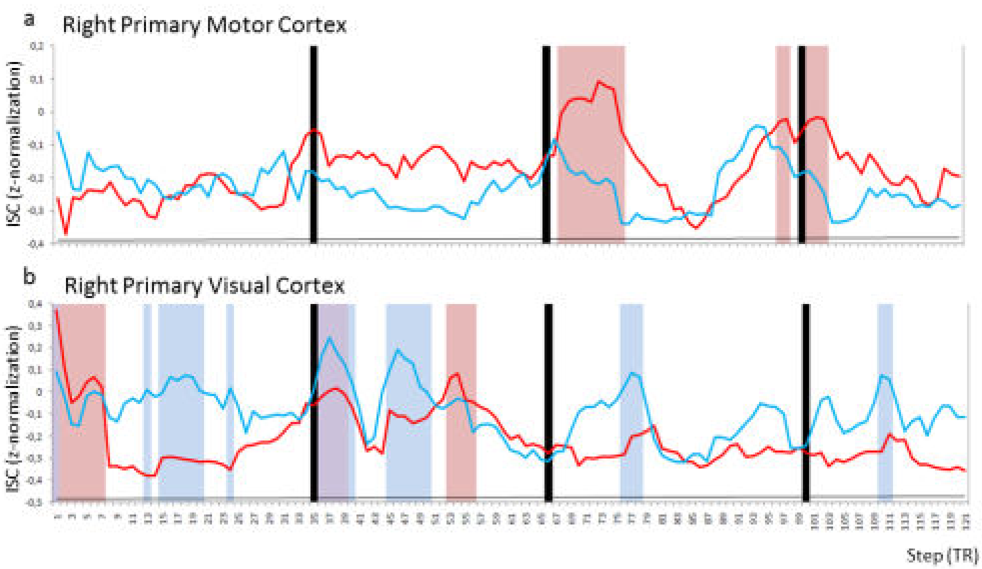

Fig3. Time-Window Inter-Subject Correlation (TW-ISC) analysis results obtained considering as regions of interest the right primary motor cortex (a) and the right primary visual cortex (b). In these graphs, to facilitate comparison between correlation timecourses of the two groups, correlations coefficients obtained comparing each pair of subjects were z-transformed and averaged to define a unique group averaged timecourse. The red and blue lines indicate respectively the time-related variation in ISC for professional and naïve drivers in the two brain areas. Red and blue bands indicate statistically significant (FDR corrected $p < 0.05$) increases in ISC in professional and naïve drivers respectively, while the violet band indicates a significant increase in both groups. These graphs show how brain activity modulation in motor areas was greater in professional as compared to naïve drivers, while a mostly opposite pattern was observable in visual cortex.

Abstract Information

References

1. Calhoun, V.D. (2011), 'A selective review of simulated driving studies: Combining naturalistic and hybrid paradigms, analysis approaches, and future directions', NeuroImage, vol. 59, no. 1, pp. 25-35.

2. Bernardi, G. (2011), 'Functional reorganization of visuo-motor cortical networks in Formula 1 pilots versus naive drivers', 17th OHBM Annual Meeting, Quebec City, Canada.

3. Sani, L. (2008), 'Expertise leads to a more efficient brain utilization: an fMRI study in professional and naïve car drivers during attention and visual-spatial tasks', 14th OHBM Annual Meeting, Melbourne, Australia.

4. Talairach, J. (1988), 'Co-planar stereotaxic atlas of the human brain', New York: Thieme Medical Publishers.

5. Cox, R.W. (1996), 'AFNI: software for analysis and visualization of functional magnetic resonance neuroimages', Computers and Biomeddical Research, vol. 29, no. 3, pp. 162-173.

6. Hasson, U. (2004), 'Intersubject synchronization of cortical activity during natural vision', Science, vol. 303, no. 5664, pp. 1634-1640.

7. Kauppi, J.P. (2010), 'Inter-subject correlation of brain hemodynamic responses during watching a movie: localization in space and frequency', Frontiers in Neuroinformatics, vol. 4:5.

8. Nummenmaa, L. (2011), 'Emotional Contagion Facilitates Social Interaction by Synchronizing Brain Activity Across Individuals', 17th OHBM Annual Meeting, Quebec City, Canada.

9. Walter, H. (2001), 'The neural correlates of driving', Neuroreport, vol. 12, no. 8, pp. 1763-1767.

10. Cattaneo, L. (2009), 'The mirror neuron system', Archives of Neurology, vol. 66, no. 5, pp. 557-560.