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

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INTRODUCTION

- Driving is a complex behavior that requires the integration of attentional, perceptual, motor and other cognitive functions
- Although many studies investigated brain activity related to driving simulation in different conditions, little is known about the neural correlates of professional competitive driving that requires greater motor and attentional skills [*Bernardi et al., 17th OHBM Annual Meeting, Quebec City, 2011*]
- Here, fMRI was used to examine functional brain activity in professional race-car as compared to naïve drivers while they watched a 'camera-car' driving of a Formula One 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

- **Subjects**: Ten **professional** (mean age±s.d. = 24±5 yrs) and 9 **naïve** (28±4 yrs) right handed healthy male car drivers
- **fMRI**: 1.5 T GE Scanner Gradient Echo EPI (TR = 2500 ms, TE = 40 ms, FA = 90°, FOV = 24 cm, IPR = 128x128, 22-26 axial slices of 5 mm thickness) and High Resolution T1 weighted SPGR images (1 mm^3 voxels)
- **Task**: Passive watching of a continuous 'camera-car' video of a Formula One car racing on four different circuits. Participants were instructed to imagine themselves driving the car
- Functional data were preprocessed and registered to the Talairach coordinate system using **AFNI** [*Cox et al., 1994*]

Inter-Subjects Correlation (ISC) Analysis

- **ISC analysis** was used to define task-related brain regions whose neural activity temporally correlated across participants [*Hasson et al., 2004*]. 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** [Kauppi et al., 2010])

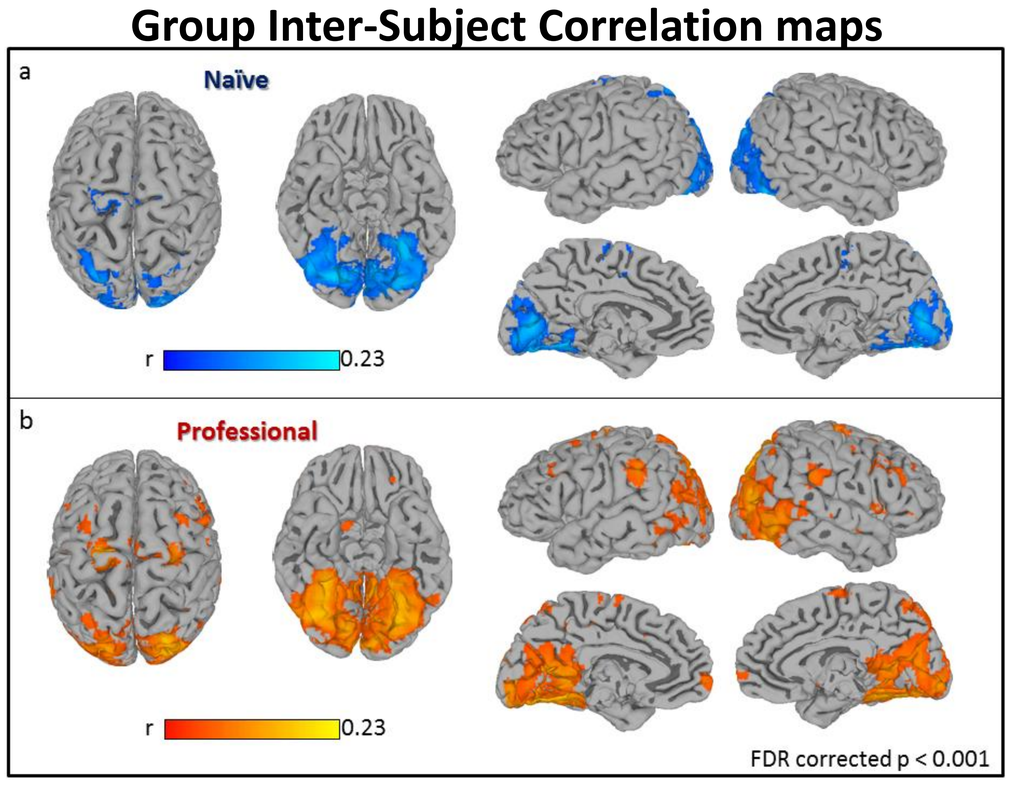
Time-Window Inter-Subjects Correlation (TW-ISC) Analysis

- To assess additional differences between groups, a **TW-ISC analysis** [*Nummenmaa et al., 17th OHBM Annual Meeting, Quebec City, 2011*] was computed 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 extracted from ISC-peaks in primary motor (**M1**) and visual (**V1**) areas for potential differences between professional and naïve drivers relatively to response properties of these regions

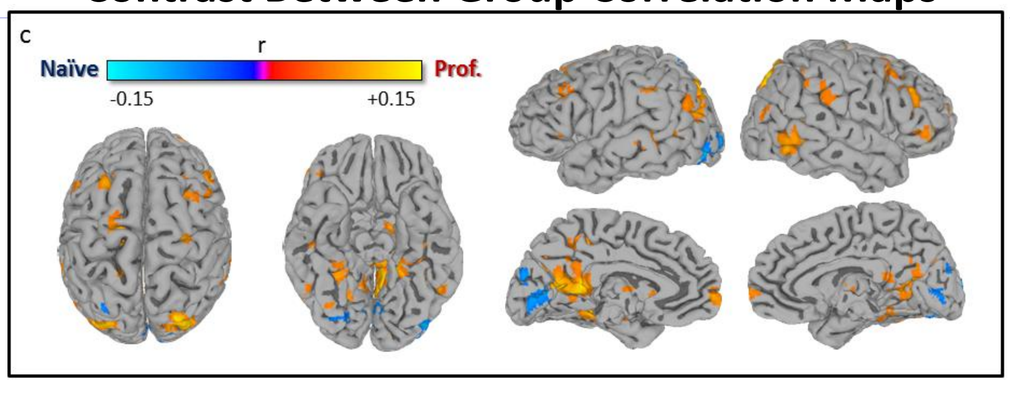
RESULTS

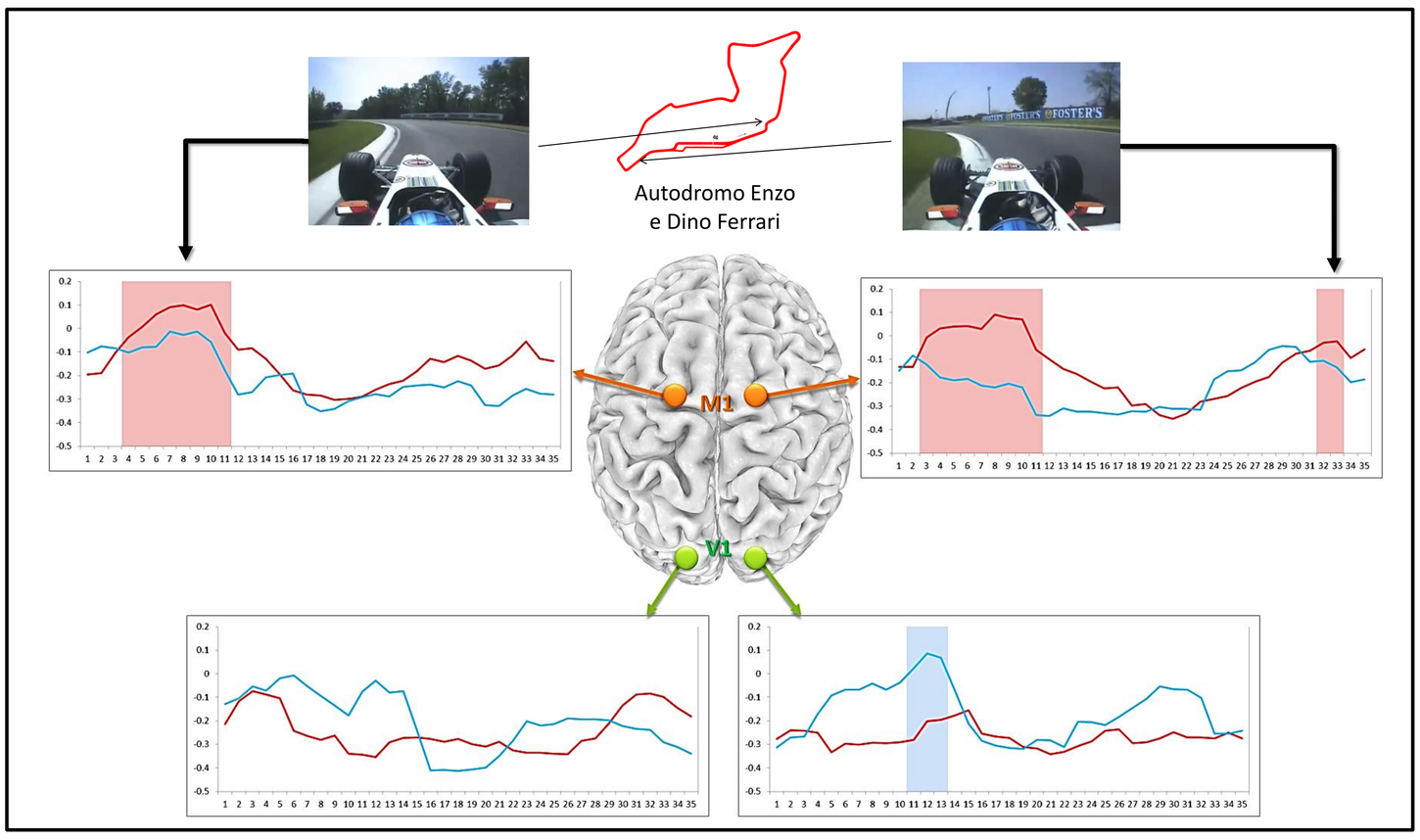
- In **both groups**, passive driving significantly modulated activity in a network of cortical **areas involved in driving behavior** [*Walter et al., 2001*], including bilateral striate and extrastriate visual cortex, precuneus, cingulate, parahippocampal, superior parietal, medial frontal and right dorsolateral prefrontal cortex, and left precentral area (Fig. **a**, **b**)
- **Professional** drivers recruited additional cortical areas, including ventral and dorsal premotor, and inferior parietal regions within the **human mirror system** [e.g., Cattaneo et al., 2009] (Fig. **c**, $p < 0.005$)

Group Inter-Subject Correlation maps



Contrast Between Group Correlation Maps





Time-Window Inter-Subject Correlation

- During each video-clip, **professional** drivers showed stronger and more frequent **correlation increases** in both left and right **M1** as compared to **naïve** drivers, who conversely showed more **correlation increases** in **V1**
- Above, the **red** and **blue lines** respectively indicate the time-related variation in ISC for **professional** and **naïve** drivers in left and right **M1** and **V1** during one of the four circuits, while red and blue **bands** indicate statistically significant (FDR-corr. $p < 0.05$) increases in ISC
- These graphs show that brain activity modulation in motor areas was greater in **professional** as compared to **naïve** drivers, while an opposite pattern was found in visual cortex

DISCUSSION

- The brain functional organization developed by **skilled race-car drivers** differs from that observed in **naïve** individuals: **professional** drivers present a higher involvement of **motor control devoted areas** while **naïve** drivers are characterized by a consistent modulation in **occipital cortex**
- 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
- **Naïve individuals simply watched the race**, while **professional drivers imagined to act**

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