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Functional reorganization of visuo-motor cortical networks in Formula 1 pilots versus naïve drivers

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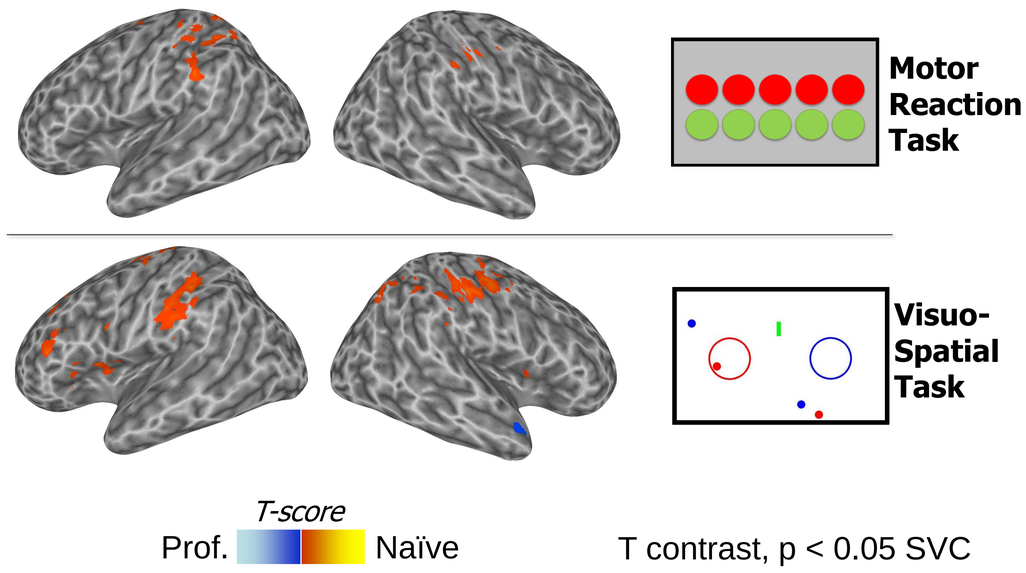
Introduction

- Recently, we showed in **professional Formula 1 racing pilots** a significantly lesser recruitment of task-relevant brain areas as compared to naïve car drivers [*Sani et al., 14th OHBM Annual Meeting, Melbourne, 2008*].

- This more parsimonious cortical recruitment, found also in other highly skilled groups [*Kelly & Garavan, 2005*], may reflect a greater **neural efficiency** associated with expertise and it has been hypothesized to be accompanied by a distinctive (re)-organization of the way task-related regions interact among themselves [*Buchel et al., 1999*].

- Here we examined whether professional racers would show distinctive patterns of task-related functional brain regional correlations as compared to naive drivers and whether such distinctive networks would be engaged even for simple tasks that do not require any particular skill. That is, we expect the **quantitatively** different brain response observed in 'expert' to imply an underlying **qualitative** modification in brain functional organization.



Methods

- **Subjects**: Eleven professional (mean age ± s.d. = 24 ± 4 yrs) and 11 naïve (28 ± 4 yrs) car drivers, all right handed healthy males

- **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)

- **Paradigm**: Six-run block design study including randomly alternated Motor Reaction (MR) and Visuo-Spatial (VS) tasks (113 volumes per run)

- **AFNI** and **SUMA** software packages for functional imaging data analysis [*http://afni.nimh.nih.gov/afni; Cox, 1996*]

- A subset of **'core' ROIs** activated in both naive and professional drivers was identified in a conjunction activation map (logical AND, uncorrected $p<10^{-5}$, k=100μL). Five-mm radius spheres were centered on across-group activation peaks, and averaged time series were calculated within each sphere.

- A **ROI-to-whole-brain** and a **whole-brain-to-ROI bivariate Granger Causality** (bGC) analysis (*3dGC.R* program; *Chen et al., 17th ISMRM Scientific Meeting, Hawaii, 2010*) for each task and subject were performed (lag = 1).

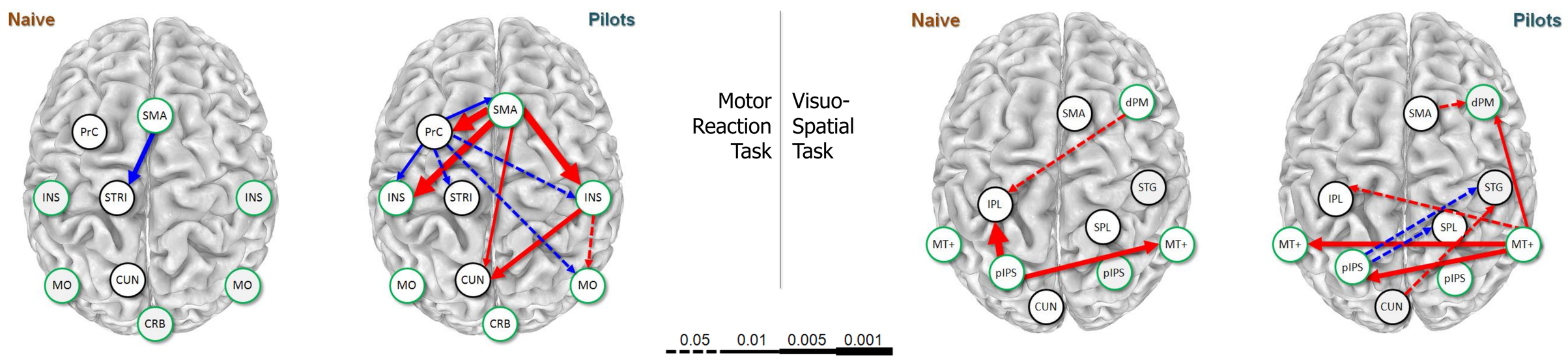
- Professional vs. naive drivers contrast were computed for each ROI, condition and task, using path coefficients and t-statistics from single subject results, with a **mixed-effect meta-analysis** approach (*3dMEMA*; *Chen et al., 16th OHBM Annual Meeting, Barcelona, 2010*).

- Two sets of **'differential' ROIs** were defined as 5-mm radius spheres centered in the contrast t-values peaks of clusters (corrected p = 0.05) that were activated during the task in at least one of the two groups.

- Finally, we included both core and differential ROIs in a **multivariate Granger Causality** (mGC) analysis (*1dGC.R*) and computed a group comparison for each task.

Results

Task-related **core regions** included: supplementary motor area (**SMA**), cerebellum (**CRB**), bilateral insula (**INS**) and middle occipital cortex (**MO**), in MR; right dorsal premotor cortex (**dPM**), bilateral middle temporal cortex (**MT+**) and posterior intraparietal sulcus (**pIPS**) in VS task. bGC analysis revealed significant group differences in how these regions interact with other brain areas, thus defining the differential ROIs included in the subsequent mGC analysis: left striatum (**STRI**), left precentral gyrus (**PrC**) and left cuneus (**CUN**) for MR; supplementary motor area (**SMA**), left inferior parietal lobule (**IPL**), right superior parietal lobule (**SPL**), cuneus (**CUN**), and superior temporal gyrus (**STG**) for VS. Results from mGC analysis, consistent with that of bGC, showed that professional drivers had numerous stronger correlations, in particular among areas of the core networks, while in naive drivers greater interactions between core and 'non-core' regions were prevalent (fig. 1-2).



Images above show results of the **between group comparisons** obtained using path coefficients and t-statistics from individual mGC analysis during each two task. **Red** and **Blue** arrows respectively indicate significantly greater **positive** and **negative correlation** with target regions (all p < 0.05 uncorrected), where a within group effect was also present (uncorrected p < 0.05). **Green** circled ROIs are that classified as '**core**' regions, while **Black** circled ROIs are '**differential**' regions obtained through the bGC analysis.

Discussion

During visuo-motor tasks reduced volumes of brain activation in professional racers were associated with both **reorganized brain networks** and **reinforced correlations among task-related areas**. As expected, these neural differences between the two groups were present during tasks that do not require any exceptional skill, as shown by the absence of any difference in task performance. These findings indicate that **neural efficiency** is a matter of **'quality'** of brain recruitment rather than **'quantity'**.

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