Linking cognitive load with mental fatigue: a resting-state functionnal connectivity approach

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Introduction

- Effortful activities involving high mental load can eventually lead to a state of mental fatigue (MF)[1].
- MF effects on the brain are twofold[2]:
  - → decreased activity in cognitive control areas;
  - → Changes in connectivity between domain-general regions monitoring our state of fatigue.
- Persisting changes in the resting-brain has been observed during periods of rest following effortful tasks inducing MF[3].

Aim of the study:

Characterize domain-general areas patterns of functional connectivity after MF induction.

Method

Participants: 17 healthy subjects (31.4 ± 5.8 y.o.; 12 women).

Experimental protocol: MF was induced by varying the cognitive load (i.e., slow vs. fast stimuli duration) during a working memory task[1].

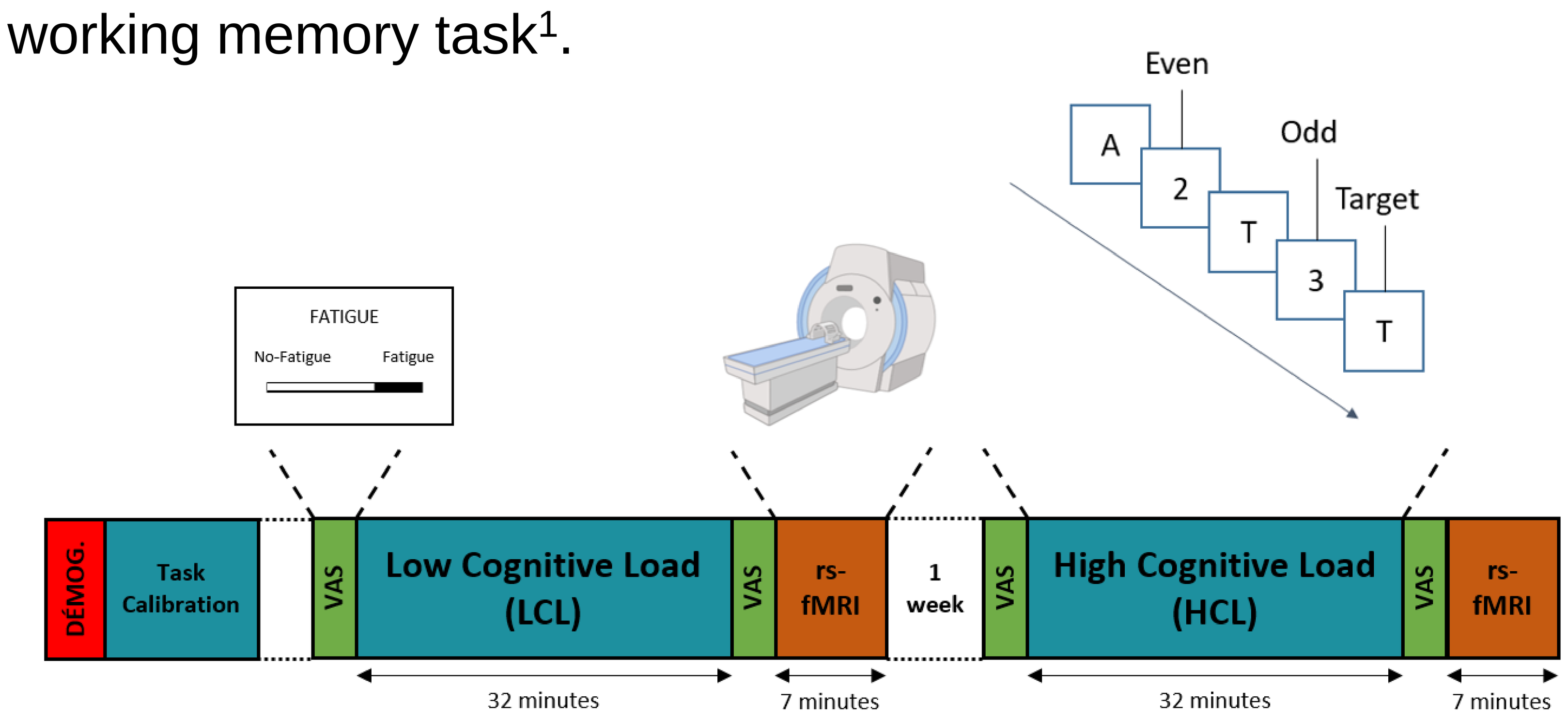

Fig. 1 | Fatigue induction protocol. Fast fatiguing (HCL) and slow control (LCL) tasks were counterbalanced between subjects. 16-minutes nBack tasks were performed before the rs-fMRI (***not shown***). Subjective measures of MF and perception of effort were acquired before and after each sessions.

rs-fMRI acquisition: Eyes open while staring at a white cross for 7 minutes (TR = 1170 ms; voxel size = 3x3x3.75 mm³).

1st level analyses: Connectivity maps were estimated for six domain-general regions known to be associated with MF[4]:

→ Insula, medial prefrontal cortex (mPFC), anterior cingulate cortex (ACC), & dorsolateral prefrontal cortex (DLPFC).

2nd level analyses: Group-level seed-based connectivity (gSBC)[5] analyses were performed to compare HCL over LCL.

→ Thresholds: $p < .001$ (voxel) & p-FDR < .05 (cluster)

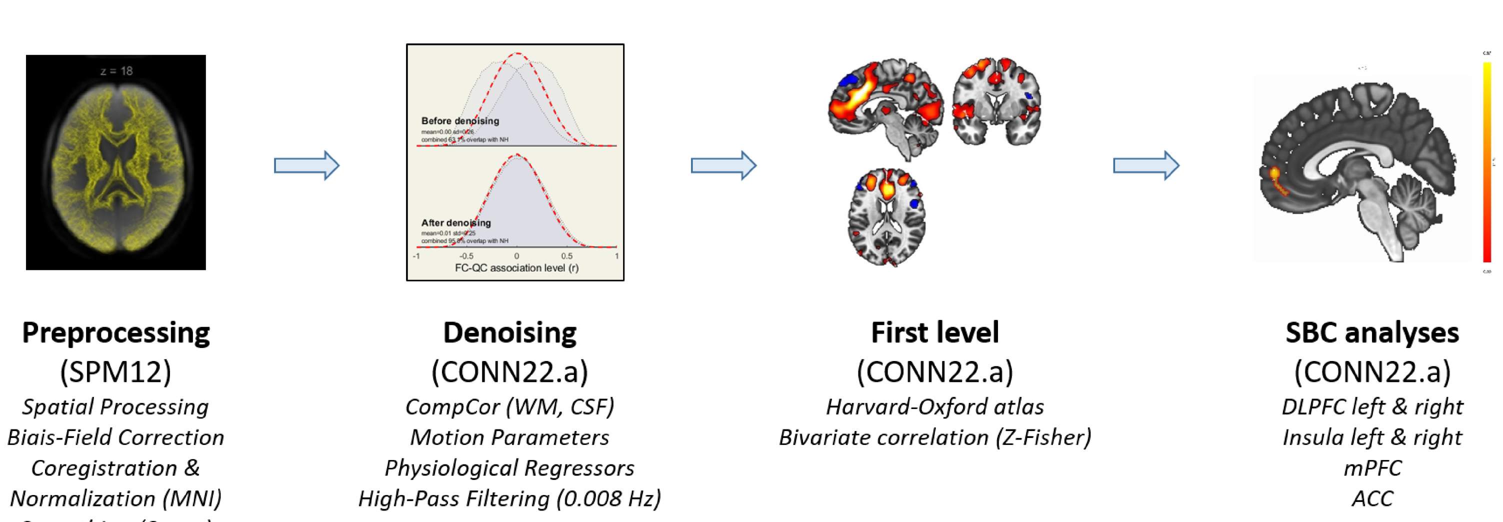

Fig. 2 | Connectivity analyses pipeline.

Results

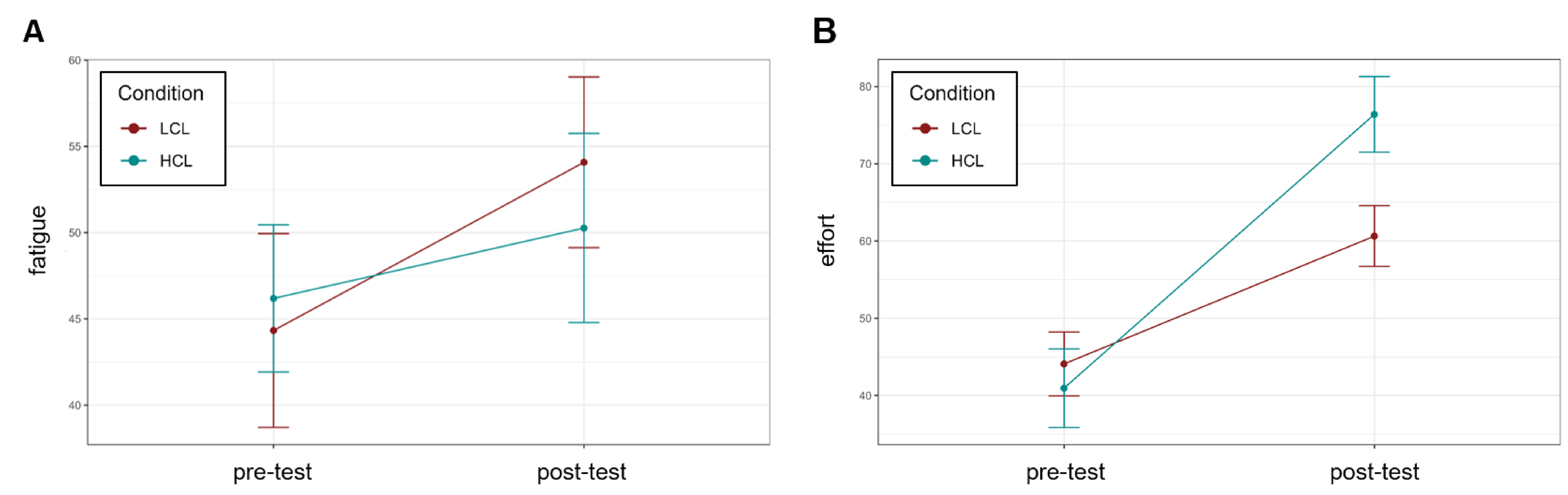

Fig. 3 | Behavioral results. Linear-mixed models showed: **(A)** a significant effect of time for the state fatigue score (F = 4.81; $p < .05$); **(B)** a significant Condition*Time interaction for the effort perception (F = 8.46; $p < .01$).

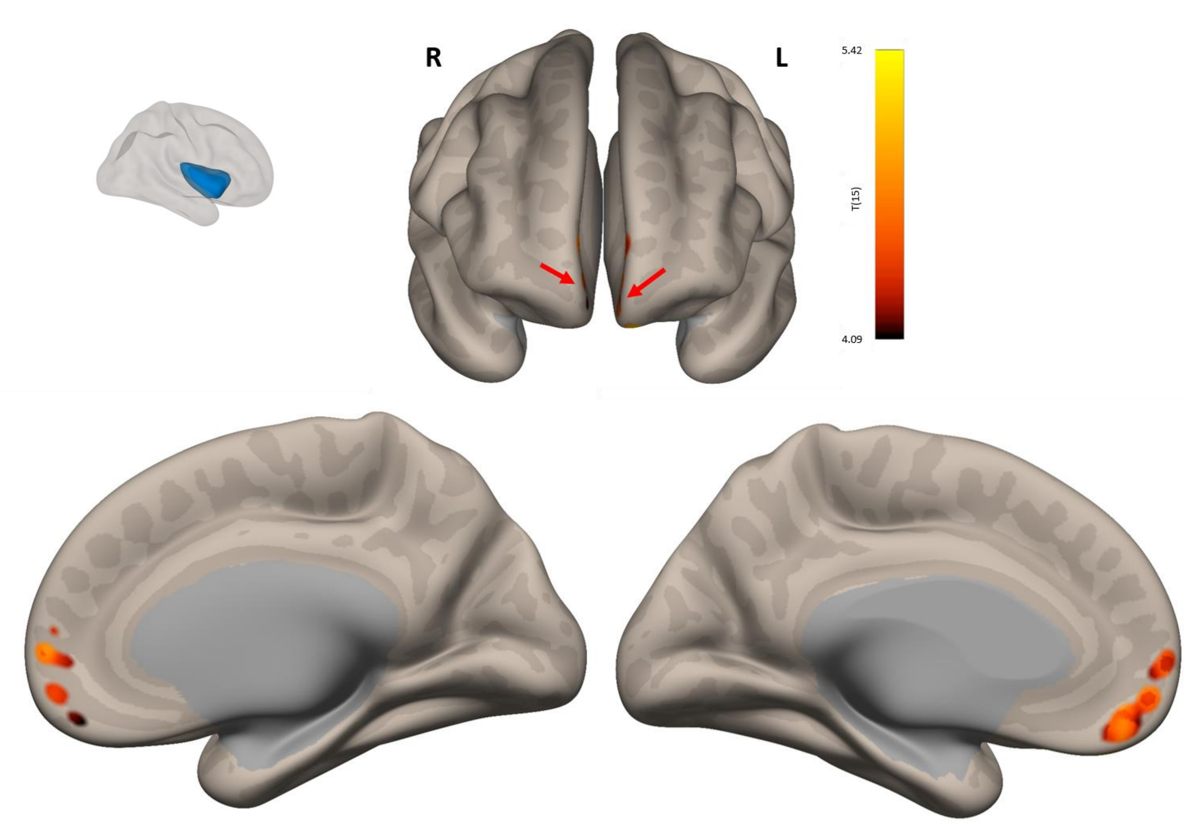

Fig. 4 | Insulas connectivity changes. Higher connectivity in LCL compared to HCL between the right insula and voxels in bilateral mPFC (95 voxels in a cluster of total size [CS] = 252 voxels). The same pattern of results is observed for the left insula (*not shown*; 71 mPFC voxels in CS = 205).

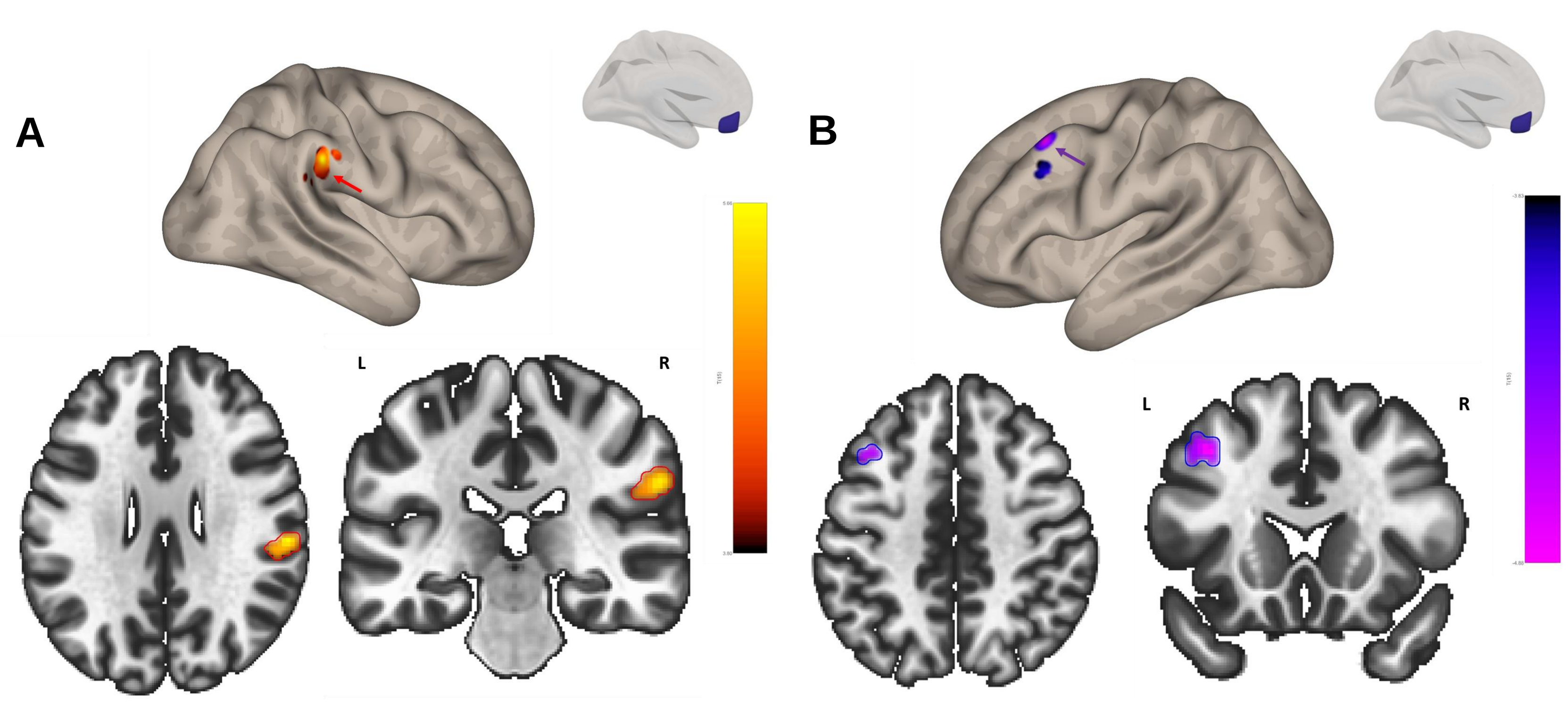

Fig. 5 | mPFC connectivity changes. **(A)** Higher connectivity in LCL compared to HCL between the mPFC and voxels in the right anterior supramarginal gyrus (65 voxels from CS = 110). **(B)** Lower connectivity in LCL compared to HCL between the mPFC and a cluster located in left middle frontal gyrus (CS = 82 voxels).

Conclusion

In line with previous studies on MF[4], our results showed:

- changes in functional connectivity between mPFC and fronto-parietal regions impacted by MF during executive tasks[6];
- lower connectivity between both insulas and a bilateral mPFC cluster in the fatigue condition compared to control.

Interestingly both insulas and mPFC are considered to take part to cost-benefit computation[7]. Even if no association with effort perception was found in the present study, it emphasizes the link between MF and effort-based decision-making.

→ These findings need a proper replication with an appropriate design and sample size.

[1]G. Borragán et al., *Cortex* **89**, (2017); [2]T. Müller & M. Apps, *Neuropsy.* **123**, (2019); [3]M. Gergelyfi et al., *NeuroImage* **243**, (2021); [4]G. Wylie et al., *Sci. Rep.* **10**, (2020); [5]A. Nieto-Castanon, *Hilbert Press*, (2020); [6]A. Owen et al., *Hum. Brain Mapp.* **25**, (2005); [7]M. Pessiglione et al., *Brain* **141**, (2018)

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