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Abstract

Chronotype-dependent performance modulation according to time of day : a functional neuroimaging approach

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Introduction: Time of day (TOD) synchronisation of habits and behaviours reflect the specific chronotype (i.e. early, neutral or late) of a given individual. Inter-individual differences in the timing of circadian processes partially account for daily variations in neurocognitive performance, as extreme early chronotypes experience optimal arousal states in the morning, and non-optimal arousal states in the evening, whereas late chronotypes exhibit the opposite profile. Here, we looked at the cerebral networks involved in arousal regulation as a combined function of the chronotype (extreme early vs. late) and the TOD at which the testing session is administered.

Methods: Fifteen extreme early chronotypes (mean age 24,9; 7 men/8 women, mean bedtime 22PM) and 15 extreme late chronotypes (mean age 24,6; 7 men/8 women, mean bedtime 3AM), healthy volunteers, each underwent 2 separate fMRI sessions: one 1h30 after their wake up time and the other 10h30 after wake up. Importantly, testing times were adapted to the individual's preferred sleep-wake timing, not to external, arbitrary clock hours. During the fMRI session, subjects performed on an adapted version of the Psychomotor Vigilance Task (Dinges, 1989), a simple reaction time (RT) task evaluating sustained attention. MRI images were acquired using a 3T Allegra MRscan (Siemens, Germany; 32 slices, voxel size:3.4x3.4x3, TR:2130 ms, TE:40 ms, FA:90°). Data were analysed using SPM5. Individual fMRI time series were modelled using a general linear model assessing brain responses to psychomotor events. Linear contrasts assessed the main effect of the task, of TOD, of chronotype and their interactions. Individual summary statistical images were then entered in a second level, random effect analysis. Statistical inferences were made at $p<0.05$, corrected for multiple comparison over a small volume of interest.

Results: *Behaviour*: Figure 1 shows a significant interaction between chronotype and TOD ($p < .05$), with significantly higher RTs in the morning than in the evening in late chronotypes.

fMRI : *Main effect of the task*: psychomotor events in the PVT activated a widely distributed attentional network.

Interaction (main effect of the task)(chronotype)*(TOD)*: during PVT performance, thalamic response (Z=3.28, coord: -6, -12, 0 mm; Figure2) was significantly higher in both groups at non-optimal arousal states according to the chronotype, i.e. higher activation was observed in the evening for early types, and in the morning for late types. Conversely, brainstem (Z=3.29, coord:-4,-10,-24mm, Figure 3) activation was higher at optimal arousal states, defined as a function of the chronotype.

Discussion : Thalamic and brainstem regions were activated at opposite TOD as a function of the specific chronotype of the subjects. Other brain regions encompassing the attentional network, activated during PVT performance, did not significantly

change their activity as a function of TOD or chronotype. These results suggest that brain structures involved in arousal regulation are differentially activated in individuals with extreme late vs. early chronotype, as a function of the TOD at which the testing session is administered.