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Stroop-related cerebral activity is modulated by time of day and chronotype

Christina Schmidt, Philippe Peigneux, Yves Leclercq, Virginie Sterpenich, Gilles Vandewalle, Pierre Berthomier, Christian Berthomier, Christophe Phillips, Michael Hogge, Gilberte Tinguely, Annabelle Darsaud, Steffen Gais, Manuel Schabus, Martin Desseilles, Thanh DangVu, Eric Salmon, Christian Degueldre, Evelyne Balteau, André Luxen, Pierre Maquet, Christian Cajochen, Fabienne Collette

Time of day (TOD) modulations are observed in behaviour and cognition. Humans differ in the synchronization of a series of habits reflecting their specific chronotype, such that some people perform best in the morning (morning types, MT) whereas others perform better in the evening (evening types, ET). Chronotype-specific performance modulation over a normal waking day have particularly been observed for cognitive parameters requiring controlled processing including regulation of distraction and of strong responses. Accordingly, we hypothesized that the cerebral correlates of the Stroop effect investigating perceptual inhibition abilities would be different in MT and ET in function of the TOD at which testing took place.
Method: Sixteen extreme MT (9w/7m; age: 24.75 ± 3.9, mean bed time: 22:24 ± 8') and 15 extreme ET (8w/7m; age: 23.5 ± 4.1; mean bed time: 02:50 ± 15') participated in the study. Each subject underwent 2 fMRI sessions, one 1h30 (morning) and the other 10h30 (evening) after awakening, thus adapting testing time to each individual's sleep wake schedule. Subjects performed a Stroop task, where they had to name the colour of a printed colour word ('red'), while ignoring the meaning of the coloured word. The task consisted in facilitatory (word colour = printed word, F), interfering (word colour ≠ printed word, I) and neutral (sequence of X's printed in a particular colour, N) trials. Functional MRI data were acquired on a 3T Allegra MR scanner (Siemens; 32 slices, voxel size:3.4x3.4x3.4mm, TR:2130 ms, TE:40 ms, FA:90°). Data were analyzed using SPM5. Individual fMRI time series were modeled using a general linear model assessing brain responses to F, I and N trial events. Linear contrasts assessed the main effect of the task, TOD and their interaction. Resulting individual summary statistical images were used in a second level analysis, corresponding to a random effect where comparisons were made at the group level according to chronotype. Statistical inferences were made at $p<0.05$, corrected for multiple comparisons over small volumes of interest.
Results: RTs were significantly slowed in I than F trials ($p<0.00001$). Even though MT felt subjectively sleepier than ET during the evening session ($p<0.05$), no significant interaction between chronotype and TOD was observed in behavioural measures of the Stroop effect ($p>0.1$). However, a main effect of conflict processing (I vs F) was evidenced in a bilateral anterior network mainly comprising the lateral prefrontal cortex, anterior insular and cingulate regions as well as the parietal lobe. Task-related BOLD activity decreased from morning to evening sessions in MT, whereas it increased throughout the day for ET in cingulate, insular, parietal and occipital regions (Figure 1a-g).
Conclusions: We observed a chronotype-specific modulation in Stroop-related BOLD activity in a couple of regions playing key roles in inhibitory functioning, according to the time of day at which the fMRI session took place. Previously reported chronotypical differences in the vulnerability to increasing time spent awake (i.e. MT more vulnerable than ETs) are potential candidates to explain such differential task-related BOLD-activity changes according to chronotype and time of day.

Figure legend :

Task-related (I>FA) responses according to time of day (morning versus evening) and chronotype. Display shows areas where BOLD activity is associated with the task-related interaction effect between chronotype and time of day [(IvsFA)*(morning versus evening)*(morning types versus evening types)]. Functional results are displayed at $p < 0.001$, uncorrected threshold, over the mean normalized structural MR image of the population. Corresponding parameter estimates (arbitrary units, interferent-facilitator) are displayed. Insular regions (a+b), cingulate cortex (C), superior (d) and inferior (e+f) parietal gyri and middle occipital (g) area.