Striatal Contribution to sleep-dependent motor consolidation

Debas, Karen[1]; Carrier, Julie[2,3]; Orban, Pierre[1]; Barakat, Marc[1]; Vandewalle, Gilles[1]; Abdallah Hadj Tahar[1]; Karni, Avi[4]; Ungerleider, Leslie G. [5]; Benali, Habib[6] and Doyon, Julien[1,3,5,6]

[1]Functional Neuroimaging Unit, University of Montreal Geriatric Institute, Montreal, Quebec, Canada
[2]Centre d'étude du sommeil et des rythmes biologiques, Hôpital du Sacré-Cœur de Montréal, Montreal, Quebec, Canada
[3]Centre de recherche en neuropsychologie et en cognition, Department of Psychology, University of Montreal, Montreal, Quebec, Canada
[4]Laboratory for Functional Brain Imaging and Learning Research, The Brain-Behavior Center, University of Haifa, Haifa, Israel
[5]Laboratory of Brain and Cognition, NIMH, NIH, Bethesda, MD, USA
[6]Unité Mixte de Recherche-S 678, Institut National de la Santé et de la Recherche Médicale/University of Paris 6, Centre Hospitalier Universitaire Pitié-Salpêtrière, Paris, France

Introduction

Motor skill consolidation refers to the brain plasticity taking place whereby learning results in an enduring long-term change in neural representation. This process is reflected behaviourally, among other ways, by spontaneous gains in performance after a latent time period following a training session where asymptotic performance is reached. Previously, sleep has been shown to contribute significantly to the consolidation of a finger sequence learning task, where off-line gains in performance were observable after sleep but not after the simple passage of time. Yet the neural correlates subserving this specific process remains a matter of debate as the nature of the post-training, sleep-related cerebral changes has only been shown in the framework of a sleep-deprivation paradigm (Fisher et al., 2005) or using, in the 12-hour re-test session, a paced condition that prevented the full expression of the consolidation mechanism (Walker et al., 2005).

Methods

We used a speed "fixed sequence" version of the finger sequence task. Subjects were asked in each block to produce an explicitly known 5-item sequence (i.e. 4-1-3-2-4) 20 consecutive times with their left hand as quickly as possible while using a response box. Twenty-four subjects were assigned to two groups: Night/sleep and Day/awake groups. Each group went through training, immediate post-training test and delayed re-test sessions, consisting of 8 blocks of practice each. In the Night/sleep group (n=13), subjects were asked to : a) learn the sequence around 9:00 p.m b) be scanned immediately after training while performing the sequence or a rest condition, c) sleep in the lab, and d) be retested while being scanned 12 hours after. In the Day/awake group (n=11), subjects remained awake and the training and first scanning sessions were carried out at 9:00 a.m., with retesting 12 hours later (Fig1).

Results

Behavioural- Data were normalised with respect to the last 5 blocs of the post-training test for each subject individually, as this is where asymptotic performance was reached

(Fig2), and because it allows to better appreciate group differences at retest. In the post-training test session, an ANOVA for repeated measures yielded no main effect of Bloc, Group, nor any Bloc x Group interaction, suggesting that all subjects had reached an asymptote. As expected, however, the Night/sleep group revealed a significant improvement in performance at retest, while the Day/awake group did not (Group x Session interaction: $F(1,22) = 5.31$, p = .03).

fMRI - Functional images were spatially preprocessed (motion correction, realignment, normalisation, smoothing) and analysed using SPM2. A conjunction analysis (Fig3) showed that both groups started off with increased activity in M1 and the cerebellum during the immediate post-training session. Different patterns of activity were observed at delayed retest, moreover, a significant Group x Session interaction (Fig4) was observed in the striatum and globus pallidus.

<u>Conclusion</u>

Our results support the hypothesis that sleep makes an important contribution to the consolidation of a motor memory trace, as well as Doyon and Ungerleider's model (2002) of motor learning, which predicts that this process is dependent upon the cortico-striatal system.
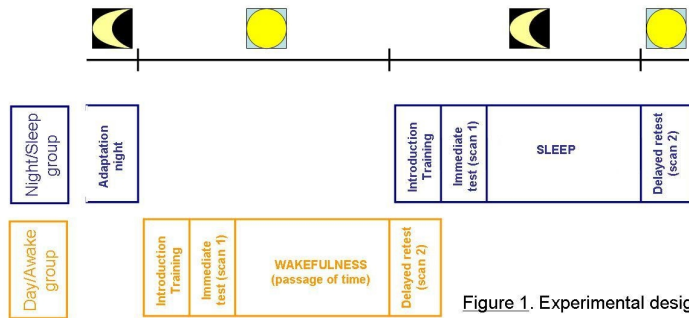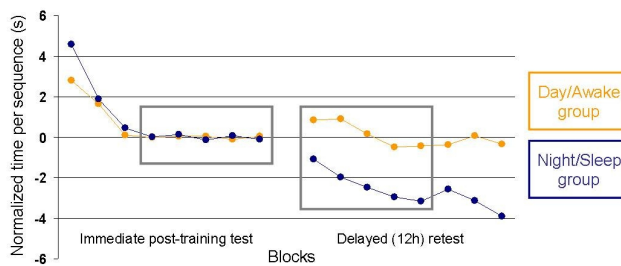

Figure 1. Experimental design

Figure 2. Behavioral results. Grey framework highlights the blocks taken into account in the analysis.
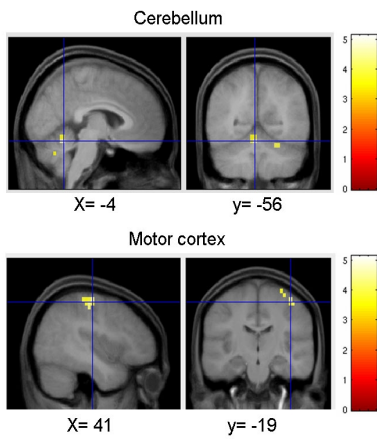
Cerebellum

X= -4   y= -56

Motor cortex

X= 41   y= -19

Figure 3. Conjunction (both groups) effect at immediate post-training test. Activation map displayed at *p* < .001 (uncorrected).

Striatum

Z= -5

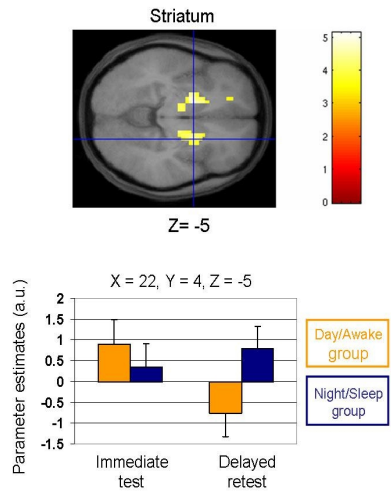X = 22, Y = 4, Z = -5

Day/Awake group

Night/Sleep group

Figure 4. Interaction (Group x Session) effect. Activation map displayed at *p* < .001 (uncorrected).