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Chama Belkhiria[1], Tarak Driss[1], Remy Guillevin[2] et Giovanni de Marco[1]

[1]Laboratoire CeRSM (EA 2931),UFR STAPS, Université Paris Ouest Nanterre La Défense.
[2] Service de Radiologie, Hôpital La Pitié Salpêtrière, Paris
belkhiriachema@hotmail.fr

Introduction

Many studies investigated the effects of force production on cerebral cortical and subcortical activity using fMRI, but few studies tested the hypothesis that cognitive states can selectively influence motor-related neural activity in cerebellum, as evidence for an integration of motion and cognition. In neuro-imaging and mental health fields, investigations taught that the cerebellum functions primarily as a co-processor (computation) of movement in concert with the cortex and basal ganglia. This motor function is thought to be localized within the right lobule V of cerebellum (Culmen) in right handed subjects. Recently, diverse views supported the idea that the cerebellum played variety of important roles across a range of cognitive and emotional functions (Kuper et al.,2011). Besides the motor and cognitive cerebellum evoked regions, we propose that some regions of the right cerebellum, notably the lobules VI-VII (Crus I/II) could play a role to integrate motion and cognition. Moreover the role of the lobules VI-VII is not yet well known from literature, it is important to identify the function of these structures to better understand the cerebellum capacity. Therefore, on the basis of anatomical and empirical assumptions, we assume, from a motor auditory verbal dual task, that lobules VI-VII (Crus I/II) in right cerebellum could deal with motor and cognitive processes and then could be a center of neural integration of motion and cognitive information.

Methods

Twelve right-handed young volunteers (six men and six women, aged 31.3±5.4 years) participated in the fMRI study. They were motivated and well concentrated to performan exercise of voluntary maximal force. The subjects squeezed a handgrip as hard and fast as possible during 4.4slying in the MR scanner (3T). There were two conditions: i) squeezing with verbal encouragement: subjects were verbally encouraged throughout the force production. ii) Squeezing without verbal encouragement. Each run included 5 trials of force production followed by a rest period of 44 seconds. We measured within lobules VII, during the squeeze period, Blood Oxygen Level Dependent signal change ratio % between verbal and no verbal conditions. Likewise force (kg) was calculated corresponding to a maximal voluntary contraction (MVC) averaged over the 5trials. Force index (kg) was defined as the subtraction between MVC obtained during the Verbal condition and MVC obtained during the No verbal condition for each subject. This force index represented the effect of the encouragement on the force execution. A correlational analysis between force index and % signal change among lobules VII was performed. A t-test was done according to the null hypothesis that the Pearson's coefficient correlation was equal to zero ($p = 0.05$) (figure1). In this study, we also measured effective connectivity using psychophysiological interactions analysis (PPI) (Friston et al., 1997). PPI analysis is a computational method that allows measuring the magnitude of functional coupling between two brain regions and reveals the dynamics of brain network. The PPI analysis explains the activity of a target region as a result of an interaction between the activity of a source region and the experimental context (encouragement). It is an approach based on cross-correlation of activation time course of a target region with the time course of a reference region (source). Basically, in the PPI approach we tried to show that the effective connectivity between two brain regions could change in presence of encouragements. We presented here a PPI between Wernicke (source) and Broca (target) regions.

Results

Figure 1 shows that cerebellar activity linearly increases with force and verbal encouragements in the lobule VII (r=0.52). Figure 2 shows the location of Wernicke and Brocas's areas Source area was Wernickea and target area was Broca. Figure 3 represents a PPI map showing significant activity within the right cerebellum (T=1.85).

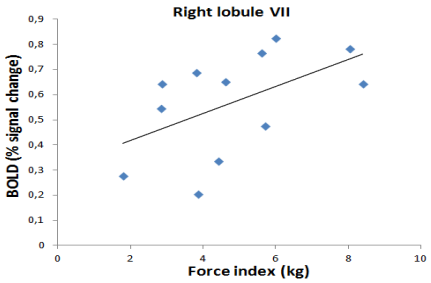

Figure 1. Correlation between % signal change and force index (between verbal and no verbal condition) in the right lobule VII of the cerebellum

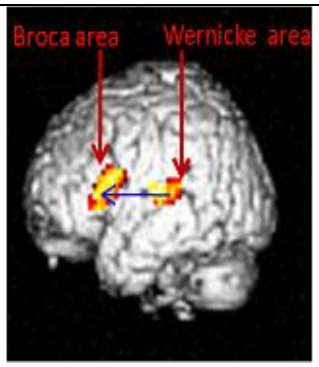

Figure 2. Location of Wernicke and Broca's areas

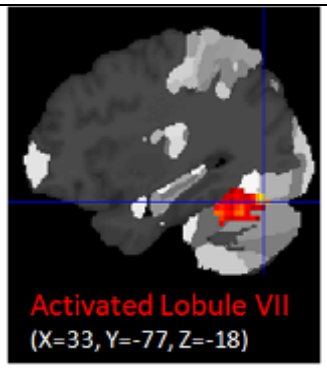

Figure 3. Activity of interaction between Wernicke (source) and Broca (target) in right cerebellum

Discussion

Emerging evidence suggests that the lobules V and VI support motor and cognitive segregated functions respectively. We propose, in this study, that the right lobules VI-VII (CrusI/II) could integrate motor and cognitive functions**.** The positive correlation (r=52) between percentage of BOLD signal change and force index in presence of encouragements in the right lobule VII of the cerebellum, showed the involvement of lobule VII in the dual task. Indeed, the literature shows that lobule VII (Crus I/II) has been shown to correlate with the SMA and parts of the lateral motor cortex, supporting the idea that lobule VII is involved in motor control (Schlerf et al., 2010). Our motor auditory verbal dual task involves motor skills but also engages cognitive processes such as words listening, concentration, attention and motivation (encouragement). Classically, the studies demonstrate that language function is conducted in the brain through the arcuate fasciculus by Wernicke's and Broca's areas localized in the inferior cortex of the left frontal lobe. In our study, the PPI analysis showed significant activity in right cerebellum while interactions between Wernicke and Broca's (T=1.85) (Figure 3). In support of potentially relevant lateralized cerebellar language activation, the cerebellum presents strong neuroanatomical connectivity with the contralateral frontal lobe, including Broca's area (Stoodley,1996). Besides, the cerebellum may be involved in the attention control because anatomical studies proved connections between right dorsolateral prefrontal cortex, parietal and cerebellum (Middleton, 2000). The existence of anatomical pathways and significant interactions from prefrontal areas to the right cerebellum provides compelling evidence that the lobule VII may manage cognitive and motor processes, and precisely at the lobule VII (Crus I/II) may play a significant role to integrate motor and auditory verbal information. It might be interesting to examine the role of the lobule VI also activated in our study.

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