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Inhibition of number-length interference in a Piaget-like task in adults : a fMRI study

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RATIONALE

The object of this fMRI study was to explore, in adults, the neural networks involved in the resolution of a Piaget-like task, i.e. to observe in adults brains the cerebral markers of a particular childhood developmental stage.

The developmental psychologist Jean Piaget studied the numerical cognition with children. One of his tasks consisted in showing two rows of objects containing the same number of objects but of different lengths and asking the children whether the two rows have the same number of objects (1). Before 7/8 years-old, the children fail in this number conservation task and reply that there were more objects in the longer row. It was proposed by Houdé that to succeed in this cognitive task, the children have to inhibit a misleading strategy (2), namely the visuospatial length-equals-number strategy.

METHODS

Subjects

12 subjects right-handed participated in the study. All gave their written informed consent and the local ethical committee approved the study.

Task

Experimental conditions: **the subjects had to judge the numerical equivalence of two rows displayed on a computer screen**, either in a Piaget-like task with a number/length interference (INT condition) or in a control task where the number and the length covaried (COV condition). They were instructed to respond by pressing the "same-number" button or the "not-same-number" button.

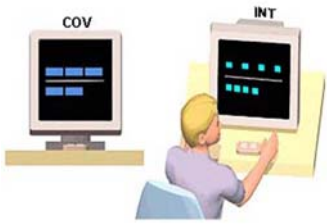


Image acquisition : MRI scanner 1.5 T GE

The task consisted in two runs with a block design. The first run consisted of six 24-sec blocks of COV condition interleaved with 24-sec of cross fixation blocks. In the second run, COV condition was replaced by INT condition. Performance and reaction times (RTs) were recorded.

For each subject, we acquired a high resolution anatomical image (T1 weighted sequence), and two functional runs with 110 functional EPI volumes each (BOLD contrast, TR = 3 sec, TE = 60 msec, FA = 90°, 21 axial slices per volume).

Analyses

Each subject data were stereotaxically normalized on the T1-MNI single subject template. The functional data were analyzed using an anatomical regions of interest (AROIs) approach (3). For each of the 90 AROIs, a BOLD signal average was computed for each condition (COV, INT), in reference to the cross fixation signal.

For each AROI, two statistical analyses were conducted :

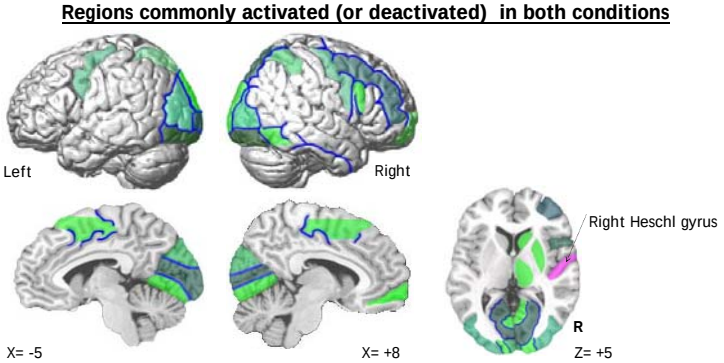
- firstly, We reported the AROIS commonly activated (or deactivated) in both conditions COV and INT) ($p<0.05$ uncorrected for each, two one-sided t-tests).
- secondly, COV and INT conditions were contrasted to shed light on the condition specific AROIs ($p<0.05$ uncorrected, paired Student t-test).

RESULTS and DISCUSSION

Behavioural data

We found significant longer RTs ($p < 0.001$) in INT condition (731 ± 72 ms) than in COV condition (540 ± 71 ms), which we believe to be a classical marker of an interference effect. The subjects made a few errors (less than 2% in each condition), which was expected as it was known that this child-psychology task is succeeded as early as 7/8 years-old (2) (4).

Regions commonly activated (or deactivated) in both conditions

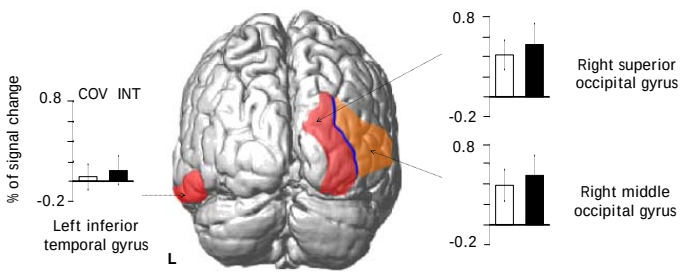


We observed bilateral activations in the occipital cortex which correspond to the identification of the visual stimulations, in the parietal cortex for the spatial exploration of the shapes, and in the pre-central cortex and the SMA for the motor response.

The activation of the right network, and in particular in the frontal cortex, was attributed to the recruitment of the object / spatial working memory processes.

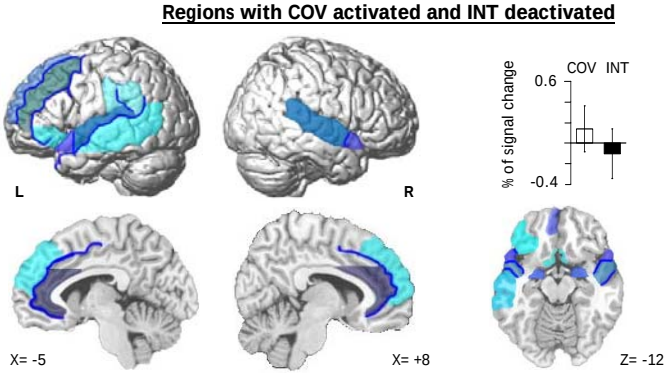
The only deactivation was found in the Heschl gyrus. It was previously described by authors as an auditory disengagement for the benefit of the visual modality, particularly on the right, for a numerical task (5).

Regions in which INT was more activated than COV



During the INT condition, the right superior and middle occipital gyrus were more activated than in the COV condition, as was the left inferior temporal gyrus . This original result shows that in a numerical task with a visuo-spatial stimulus, the executive function (here, the inhibitory control) is processed in posterior areas. Note that these results are in contradiction to what was found in other logico-mathematical tasks, like reasonning with linguistic rules, where the executive functions were described as processed by the medial orbital prefrontal regions (6).

Regions with COV activated and INT deactivated



The INT deactivation in the left lateralized frontal AROIS, was already reported during numerical tasks (7), and could be considered as a inter-hemispheric balance phenomenon (8) as the right occipital visuospatial areas were particularly enhanced for the executive function in the INT condition.

The pattern of activation / deactivation in the bilateral regions of the limbic and paralimbic networks, had recently been reported by authors as a balance between the increase of cognitive demand (here the inhibition of a misleading strategy) and the lowered activity in emotional regions (9).

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