THE NEURAL BASIS OF PROACTIVE AND REACTIVE CONTROL PROCESSES IN NORMAL AGING

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INTRODUCTION

We investigated the effect of normal aging on the neural substrates of inhibition in a Stroop task according to contextual information. Based on the dual cognitive control model [1], two task-contexts were created: (1) *congruent* context with a majority of facilitator items, involving **reactive control** (occurring transiently after an interfering item); (2) *non-congruent* context with mainly interfering items, involving **proactive control** (anticipatory and sustained across the context). Neuroimaging data indicated that proactive control was associated to **sustained** activity in the lateral prefrontal cortex (PFC) while the reactive control depends on **transient** activity in the ACC and lateral PFC (2,3,4]. With regard to healthy aging, **impairment in proactive control** was observed while reactive control strategies seems to remains intact [5,6]

On this basis, we hypothesized the presence of age-related effects on the neural substrates of proactive *(decreased activity in the ACC)* and reactive *(increased activity in the lateral PFC)* control processes.

METHODS

Twenty right-handed French speakers young (21 to 30 y.) and older (61 to 74 y.) adults were recruited. Older adults had a score >130 to the Mattis dementia Rating Scale.

A modified form of the Stroop task [3] was administered in a fMRI session. The Stroop paradigm consists in the inhibition of a predominant response (WORD READING) to promote another one (COLOR NAMING).

Three kinds of items

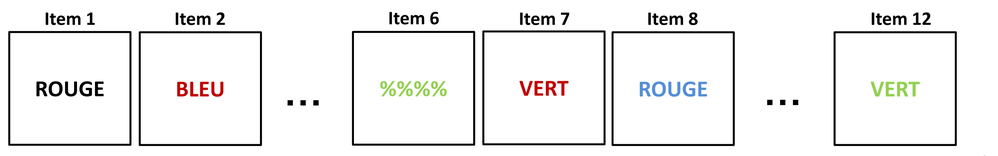
BLUE	RED	%%%%
Interfering Items (**II**)	Facilitator/congruent Items (**CI**)	Neutral Items (**NI**)

Three kinds of contexts (15 blocks of 12 items by context)

8II – 2CI – 2NI	8CI – 2II – 2NI	8NI – 2II – 2CI
Mostly incongruent context (MI)	Mostly congruent context (MC)	Mostly neutral context (MN)

=> Proactive control was implemented by MI blocks and reactive control by MC blocks.

Task : To name the ink color as fast and accurately as possible by pressing the corresponding key-response at the bottom of the screen.



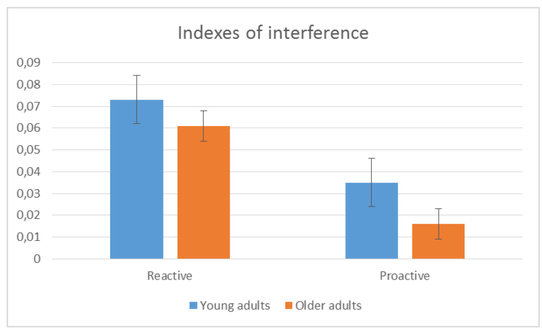
Brain imaging data were acquired on a 3T head-only scanner. Multislice T2*-weighted functional images were acquired with a gradient-echo echo-planar imaging sequence using axial slice orientation and covering the whole brain (32 slices, FoV = 220x220 mm², voxel size 3.4x3.4x3 mm³, 30% interslice gap, matrix size 64x64x32, TR = 2130 ms, TE = 40 ms, FA = 90°). Structural images were obtained using a high resolution T1-weighted sequence (3D MDEFT [9] ; TR = 7.92 ms, TE = 2.4 ms, TI = 910 ms, FA = 15°, FoV = 256 x 224 x 176 mm³, 1 mm isotropic spatial resolution).

Preprocessing and statistical analyses were performed using SPM8 software. A 2-step analysis accounting for fixed and random effects was performed. At the first level (fixed effect analysis), the hemodynamic response specifically associated to reactive control *(II vs NI in MC context)* and to proactive control *(II, CI and NI in MI vs MC)* was computed for each subject. At the second level (random effect analysis), brain areas specifically associated to the same contrast were compared between groups using t-tests.

RESULTS

BEHAVIORAL RESULTS

ANOVA 2(groups) x 3(contexts)



Index of "reactivity"*: F(1,38) = 0.55, p =0,47
Index of "proactivity"**: F(1,38) = 3.05, p=0,09

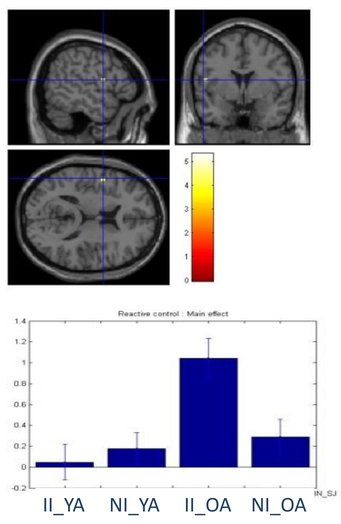
* (MC_II – MC_IN) / (MC_II + MC_IN)
** (MI_II – MC_II) / (MI_II + MC_II)

fMRI RESULTS: Group comparisons using t-test ($P_{uncorrected} < .001$)

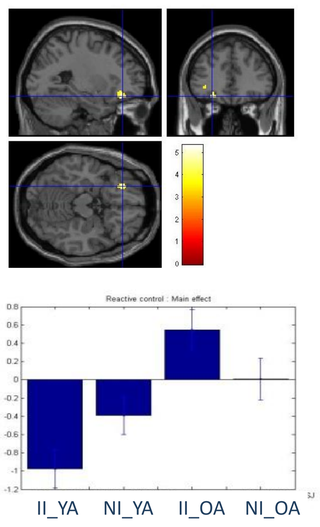
1. Reactive control : Transient activity, comparison of I and N items in MC context.

Older > young

L inferior frontal operculum*
-52+2+14



L middle frontal orbital
-26+36-16

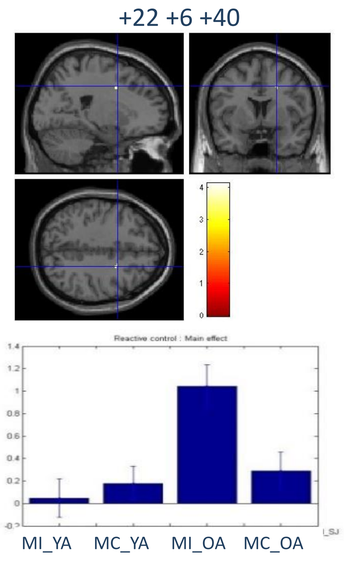


Older < young

2. : Proactive control : Sustained activity, comparison of I,F,N items in MI vs MC context

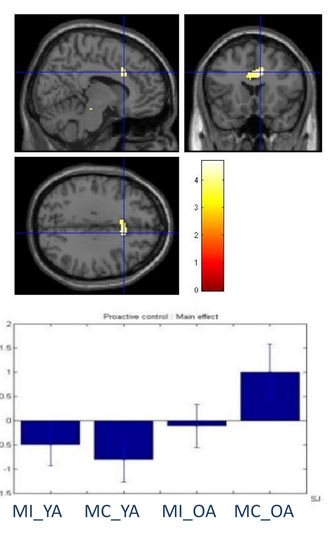
Older > young

R middle frontal*
+22 +6 +40

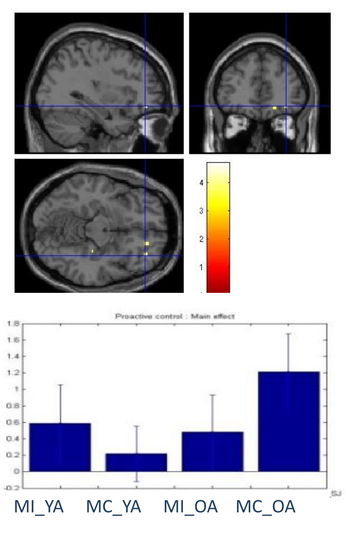


Older < young

Anterior cingulate
+10+18 +32



R inferior/frontal orbital*
+34+42 -12



DISCUSSION

We observed neural changes in healthy aging for the implementation of reactive and proactive cognitive control processes. Indeed, in the **reactive control** condition, increased activity was observed for healthy participants in the left inferior operculum, previously associated to inhibition, that could reflect compensatory processes. In the **proactive control** condition, we observed changes in the balance between areas involved in conflict detection (↓ activity in the ACC) and maintenance of task goals/contextual information (↑ activity in the right middle frontal gyrus). Importantly, these changes in neural patterns observed in older adults are very similar to those observed in young adults with low dopamine availability [4]. This seems indicate that a general mechanism (prefrontal dopamine availability) modulate brain networks associated with various kinds of cognitive control. Consequently, changes in brain activity in normal aging could not be considered as "dysfunctional" but would reflect **normal responses to a challenging environment** (i.e., few dopamine available; see also [7,8])

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