Gender differences in correlations of functional brain activation with intelligence factor scores

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Abstract Previous studies have found correlations between functional activity and cognitive performances. Furthermore, some studies have found a gender effect on these correlations. Here we sought to analyze fMRI activity and intelligence factor scores in a group of 40 normal control subjects.

Method Forty healthy subjects (19 females, 21 males) completed eight behavioral tests of the Johnson O'Connor Research Foundation's test battery, all of which have been shown to load on four factors(1)- Speed of Reasoning, Numerical, Spatial, and Memory, and a general *g-factor*-and have been used in research on various aspects of cognition and intelligence (2). Test scores were separated for sex and age in order to eliminate nuisance variance. *Image acquisition*- Scans were completed on a Siemens 3T Allegra MRI. A high resolution Axial 3D-MPRage (TR = 2500 ms, TE = 4.4 ms, FOV = 23 cm, matrix size = 256x256, 208 slices with thickness = 0.9 mm) for anatomical localization and coregistration with the EPI Bold scan (GE-EPI sequence: TR=2s, TE=27ms, FOV=21cm, 2.5mm thick, skip = 0.5mm, Matrix size=64x64, 34 slices, 246 measurements). *fMRI Paradigm*- For the functional scan, subjects performed a single letter N-back paradigm. Six trials of different N-back stimuli were presented where $N \in \{0,1,2,3\}$. Each trial was preceded by a 2s instruction screen indicating which N-back was to follow. Each trial lasted for 30s. In between the trials was a 20s rest period where the subjects were presented with a fixation screen. All subjects received instructions on the task before the imaging session. *Analysis*- BOLD data was motion corrected and coregistered with each subjects' anatomical image prior to normalization into MNI space. Individual contrast images were produced in the context of the general linear model using a boxcar function [fixation versus 0, 1, 2, 3-back] convolved with a canonical haemodynamic response function. A one-sample t-test ($p<.001$) was performed using each subjects' contrast images to determine areas of increased activity during the active (0,1,2,3-back) state compared to baseline (fixation). The following clusters of activation were identified: Anterior Cingulate (ACC), Prefrontal Cortex (PFC), Parietal cortex (PC), Insular Cortex (IC) and visual cortex (VC) (Fig 1). Percent activation for these clusters were extracted for the individual subjects and transferred to Statistica V7 (Statsoft Inc., Tulsa, OK) for correlation analysis with intelligence factor scores.

Results Correlation analysis of all subjects revealed significant negative correlations for spatial factors in the right prefrontal cortex ($r=-0.351$, $p<0.026$), and right posterior parietal cortex ($r=-0.393$, $p<0.012$). There was also a negative correlation for the G-factor in the right parietal cortex ($r=-0.338$, $p<0.033$). When the data was parceled out by gender, males displayed negative correlations with spatial factors in the right prefrontal cortex ($r=-0.582$, $p<0.006$), right posterior parietal cortex ($r=-0.454$, $p<0.039$), and also a negative correlation with G-factor in the right prefrontal cortex ($r=-0.452$, $p<0.040$). Females displayed negative correlations between brain activity and numerical factors in the Anterior Cingulate ($r=-0.503$, $p<0.028$), as well as left ($r=-0.548$, $p<0.015$) and right ($r=-0.501$, $p<0.029$) posterior parietal cortices. Females also displayed negative correlations with reasoning factors in the left posterior parietal cortex ($r=-0.477$, $p<0.039$) and negative correlations with G-factor in the left ($r=-0.516$, $p<0.024$) and right ($r=-0.496$, $p<0.31$) posterior parietal cortices.

Discussion General fluid intelligence (G*f*) refers to the ability to solve novel and complex problems in the absence of previous task-related knowledge. Working memory (WM) has been suggested as an underlying facet of G*f* and tests of WM like the N-back have been shown to be related to G*f* (7). Using the N-back task, we have found activity in various brain regions to be negatively correlated with intelligence measures, indicating reduced activity with increased performance. This is consistent with the efficiency model of brain function (3). All of the significant correlations involved the prefrontal and parietal cortices. This is also consistent with prior studies that implicated a parietal-frontal network involvement with intelligence (4). Spatial factor scores correlated with right prefrontal and posterior parietal cortex in the group analysis as well as in the male category. Although there is a general notion that spatial ability is a right hemisphere function, recent studies have found that there is a gender effect. A meta-analysis (5) showed that females are much less lateralized than their male counterparts in terms of brain function and spatial tasks. The lack of any significant correlations for spatial factors in the female population is additional support for these findings. In addition, g-factors were correlated with only the right parietal in the males but were correlated to both left and right side of the parietal cortices in females. The female group had significant correlations with numerical factors on both sides of the parietal cortex. Other studies (6) have shown that numerical abilities recruit both sides of the parietal cortex. No other studies have shown any gender effect for this function.

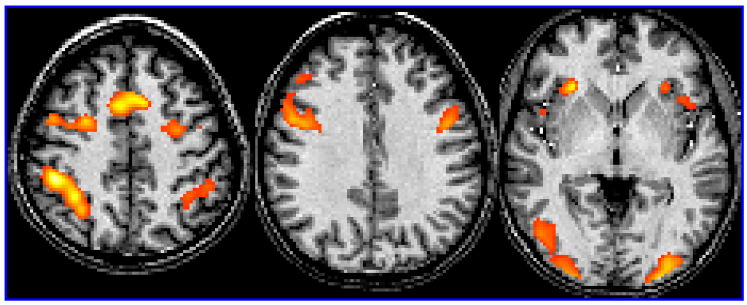

Figure 1: Group activation maps ($p<.001$) overlaid on anatomical MRI.

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