# Analyzing the association between brain network topological parameters and intellectual performance

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**Target audience:** Medical physicists and psychologists working on brain connectivity.

**Purpose:** It is known that multiple brain areas, even to an individual at rest, work synchronously even if they are anatomically separated, suggesting functional (1) and structural connections. In this way, our brain can be considered a complex network, in which nodes can be the different areas and edges can be the measurements of functional connectivity between time series of the magnetic resonance signal of each area (2). Prior studies have assessed connectivity differences in healthy control considering parameters like genre (3), age (4) and intelligence (5). In this study, we purpose to analyze the relationship between network topological parameters (characteristic path length (CPL), local efficiency (LE), local clustering coefficient (LCC), assortativity (AS) and degree of the node (DE)) and intellectual performance, using magnetic resonance images and considering weighted and binary functional connectivity networks.

**Methodology**: 21 healthy right-handed subjects participated in this study (mean age: 27,5±6,0, 11 men). This study was approved by the local Ethics on Research Committee. Revisited WAIS test was used to assess individual full-scale intelligence coefficient (FIQ) and other associated indices: verbal IQ (VIQ), performance IQ (PIQ), verbal comprehension index (VCI), perceptual organization index (POI), working memory index (WMI), and processing speed index (PSI). Functional (temporal resolution of 2 s) MR images were acquired during rest (7 minutes) using conventional EPI sequence in a 3 Tesla machine. An anatomical image (isotropical resolution of 1 mm) was also acquired using a TFE sequence. Functional images of each subject were corrected for head motion, co-registered with the anatomical image and spatially smoothed using a 5 mm FWHM Gaussian filter. These images were superposed to an individual mask and to the AAL atlas (6) and were normalized to a standard space. From processed functional images and atlas superposition, mean time-series were extracted from each atlas region (116 regions, considered the brain network nodes) and weighted and binary association matrices were created from Pearson correlation coefficient computed between pairs of time-series for each subject. Finally, topological parameters were individually estimated and linearly correlated with WAIS test indices. All the post-processing procedure was performed in MATLAB.

**Results:** AS increases with increasing FIQ, considering binary networks with threshold of 0.2, moderate correlation (figure 1). CPL length decreases with increasing WMI, considering binary networks with threshold of 0.5, moderate correlation (figure 1).

LE and LCC in right anterior cingulate cortex increase with increasing VCI, considering weighted networks, moderate correlation (figure 2). Similar results to the left side.

LE in left frontal inferior operculum, considering weighted networks, and DE increases in left precentral cortex, considering binary networks with threshold of 0.2, increase with increasing WMI, both moderate correlation (figure 3).

**Discussion:** As assortativity is a measurement directly associated to resilience, as can be seen in figure 1, individuals that exhibit higher FIQ scores may have brain networks more robust than lower ones. Moreover, individuals with higher WMI may have greater functional integration, which is inversely related to characteristic path length.

As shown in figure 2, anterior cingulate cortex may have an important role in the verbal comprehension process, since both local efficiency and local clustering coefficient increase with increasing VCI scores. These findings suggest that such index is directly related to the prevalence of clustered connectivity in anterior cingulate cortex.

Left frontal inferior operculum and left precentral cortex are associated to the left prefrontal cortex and the results are in according to Cole et al (7). This region is more efficiently and higher connected to the rest of the network for individuals exhibiting higher WMI. In general, our results suggest that higher GE can be important to an efficient processing of information by this region, what would takes to higher intelligence sub-indices.

**Conclusion:** The resting-state fMRI acquisition allows the study of associations between topological parameters of the brain network and intelligence scores. Global topological parameters, as assortativity and characteristic path length, are associated to intelligence scores, as full-scale IQ and working memory, respectively. Topological parameters as local efficiency and local clustering coefficient in anterior cingulate cortex are associated to verbal comprehension index. Topological parameters, as local efficiency and degree, in left prefrontal cortex are associated to working memory index.

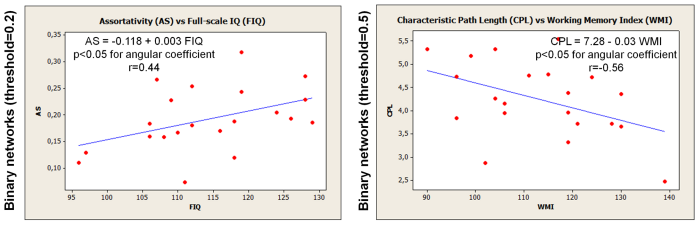


**Figure 1. Association between global topological parameters and intelligence scores.**

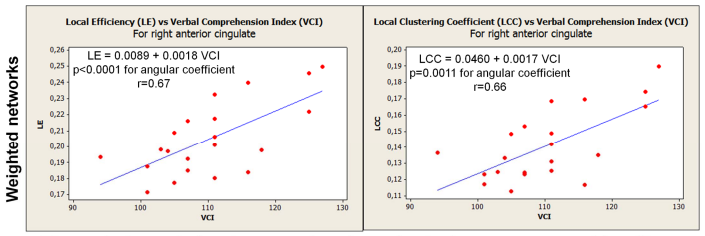


**Figure 2. Association between local topological parameters and intelligence scores for right anterior cingulate.**

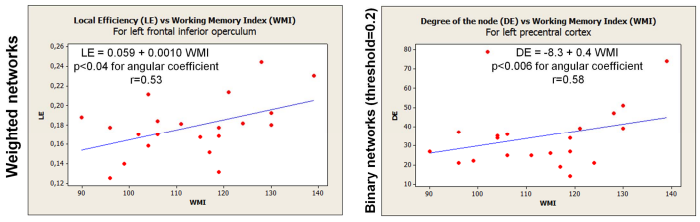


**Figure 3. Association between local topological parameters and intelligence scores for left frontal inferior operculum.**

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