Relationship Between Brain Entropy Patterns Estimated by Resting State fMRI and Child Behaviour

Authors : Sonia Boscenco, Zihan Wang, Euclides José de Mendoça Filho, João Paulo Hoppe, Irina Pokhvisneva, Geoffrey B.C. Hall, Michael J. Meaney, Patricia Pelufo Silveira

Abstract : Entropy can be described as a measure of the number of states of a system, and when used in the context of physiological time-based signals, it serves as a measure of complexity. In functional connectivity data, entropy can account for the moment-to-moment variability that is neglected in traditional functional magnetic resonance imaging (fMRI) analyses. While brain fMRI resting state entropy has been associated with some pathological conditions like schizophrenia, no investigations have explored the association between brain entropy measures and individual differences in child behavior in healthy children. We describe a novel exploratory approach to evaluate brain fMRI resting state data in two child cohorts, and MAVAN (N=54, 4.5 years, 48% males) and GUSTO (N = 206, 4.5 years, 48% males) and its associations to child behavior, that can be used in future research in the context of child exposures and long-term health. Following rs-fMRI data pre-processing and Shannon entropy calculation across 32 network regions of interest to acquire 496 unique functional connections, partial correlation coefficient analysis adjusted for sex was performed to identify associations between entropy data and Strengths and Difficulties questionnaire in MAVAN and Child Behavior Checklist domains in GUSTO. Significance was set at $p < 0.01$, and we found eight significant associations in GUSTO. Negative associations were found between two frontoparietal regions and cerebellar posterior and oppositional defiant problems, $(r = -0.212, p = 0.006)$ and $(r = -0.200, p = 0.009)$. Positive associations were identified between somatic complaints and four default mode connections: salience insula $(r = 0.202, p < 0.01)$, dorsal attention intraparietal sulcus $(r = 0.231, p = 0.003)$, language inferior frontal gyrus $(r = 0.207, p = 0.008)$ and language posterior superior temporal gyrus $(r = 0.210, p = 0.008)$. Positive associations were also found between insula and frontoparietal connection and attention deficit / hyperactivity problems $(r = 0.200, p < 0.01)$, and insula – default mode connection and pervasive developmental problems $(r = 0.210, p = 0.007)$. In MAVAN, ten significant associations were identified. Two positive associations were found = with prosocial scores: the salience prefrontal cortex and dorsal attention connection $(r = 0.474, p = 0.005)$ and the salience supramarginal gyrus and dorsal attention intraparietal sulcus $(r = 0.447, p = 0.008)$. The insula and prefrontal connection were negatively associated with peer problems $(r = -0.437, p < 0.01)$. Conduct problems were negatively associated with six separate connections, the left salience insula and right salience insula $(r = -0.449, p = 0.008)$, left salience insula and right salience supramarginal gyrus $(r = -0.512, p = 0.002)$, the default mode and visual network $(r = -0.444, p = 0.009)$, dorsal attention and language network $(r = -0.490, p = 0.003)$, and default mode and posterior parietal cortex $(r = -0.546, p = 0.001)$. Entropy measures of resting state functional connectivity can be used to identify individual differences in brain function that are correlated with variation in behavioral problems in healthy children. Further studies applying this marker into the context of environmental exposures are warranted.

Keywords : child behaviour, functional connectivity, imaging, Shannon entropy