Interaction Information Along Lifespan Reveals a Redundant Role of the Default Mode Network

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Introduction:

In this work recenty published (Camino-Pontes et al 2018), we show that the use of interaction information (II) can detect redundant or synergetic interactions in dynamical networks. Defined for a set of three variables, II measures the change in the mutual information between any two variables after adding the third. If the change is positive, a synergetic interaction occurs in the triplet, whereas if the change is negative, redundant interactions emerge (Erramuzpe et al, 2015). Therefore, whilst the mutual information (MI) shared between two variables is always positive or zero, II can be either positive or negative, respectively, unveiling redundancy (R) or synergy (S). We asses synergetic and redundant interactions along lifespan, calculating II from functional MRI in a population of participants with an age range from 10 to 80 years.

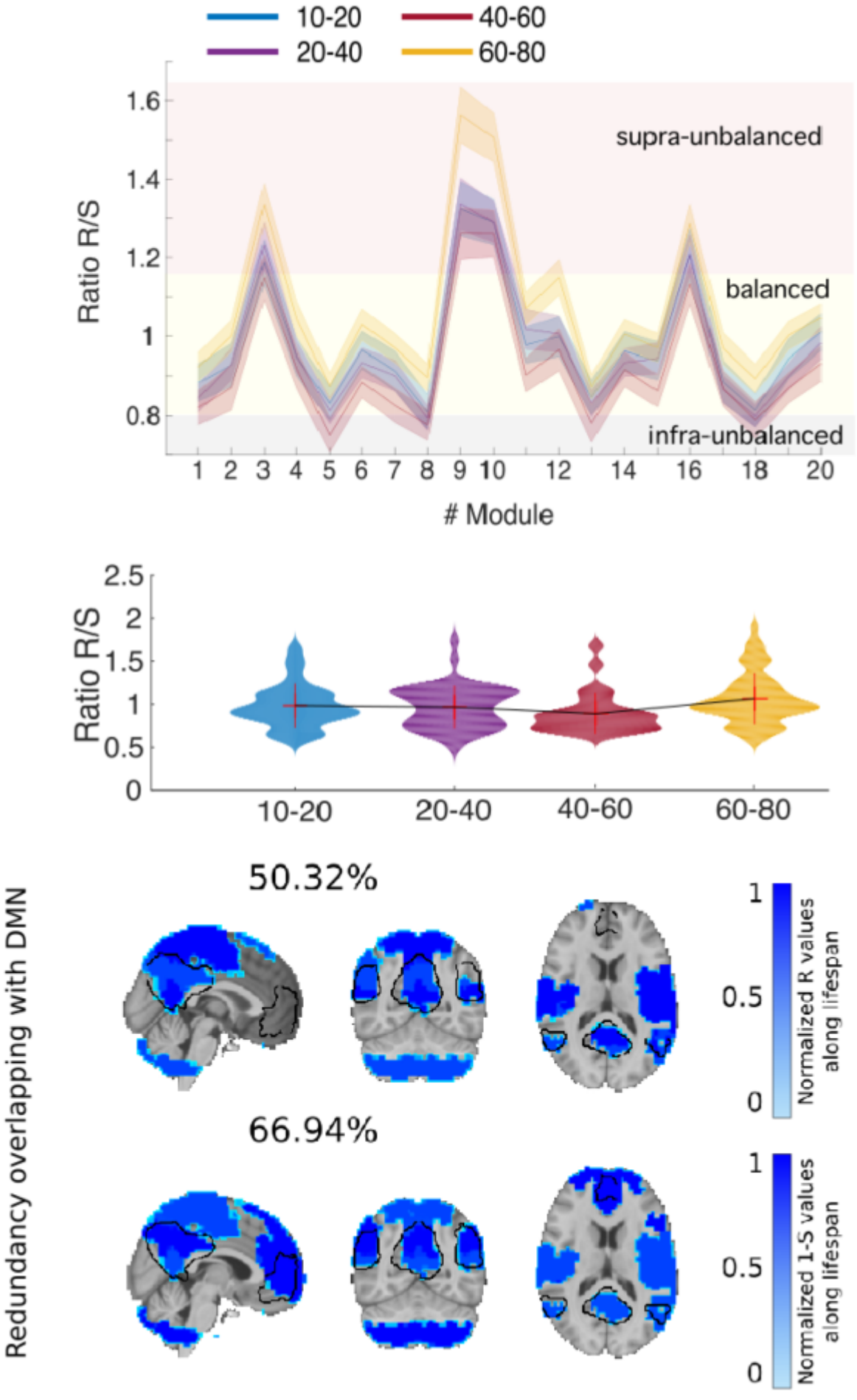
Methods:

Image acquisition was performed in a MRI Siemens 3T MAGNETOM Trio MRI scanner with a 12-channel matrix head coil. We applied resting functional MRI preprocessing similar to previous work (Rasero et al. 2017; Stramaglia et al, 2017) using FSL and AFNI. The brain was divide in 2514 using the brain hierarchical atlas (BHA), developed in (Diez et al, 2015). Here, we focus on the M=20 module partition as was shown to be optimal based on cross-modularity. For calculation of II, we used triplets (X,Y,Z) of module time series and applied $II(X,Y,Z) \cong MI(X,Y) - MI(X,Y|Z)$, estimating MI(X,Y) and MI(X,Y|Z) using the Gaussian copula approach. For statistical analysis, first, we averaged for each participant and over all brain modules R, S and R/S. Second, we performed a Kruskal-Wallis test between the values corresponding to the different age intervals. Third, we performed a Wilcoxon rank sum test as a post-hoc analysis. Fourth and last, we applied a Bonferroni correction by building a significance treshold.

Results:

Lifespan was assessed defining four different intervals of age: I1 (10–20 years), I2 (20–40 years), I3 (40–60 years) and I4 (60–80 years). Along lifespan, the average R over all brain modules showed differences between groups I3

vs. I4. Highest values were found in areas that are associated with a superposition of three important resting state networks, namely, default mode, sensory-motor and auditory networks. The average S over all brain modules showed differences between groups I1 vs. I4 and I2 vs. I4. Highest values were found in these areas that are associated with different cognitive domains, such as spatial and temporal memory, emotion processing and motor skills. We have found that the amount of R is somehow compensated by S, and this occurred for all brain modules and along lifespan. Post-hoc pairwise comparisons did not show either any significant comparison, indicating a robust balance between R and S along lifespan. Despite the effective balance between R and S (captured by the ratio R/S close to 1), however, some brain areas went beyond the balanced regime. Infra-unbalanced brain maps overlapped with the frontoparietal network. Balanced brain maps overlapped with the cerebellum and visual networks. Supra-unbalanced brain maps matched with the DMN.



·Redundant role of the Default Mode Network along lifespan.

Conclusions:

Across brain areas, high values of S were found majorly in subcortical structures, although some others were cortical, whilst R was found fully at the cerebral cortex and in the cerebellum. At the functional level, S was associated with spatial and temporal memory, emotion processing and motor skills, whereas R was associated with sensory processing (auditory and visual) and to a major extent to the DMN. We have shown that the amount of R and S are roughly balanced (as the ratio R/S tends to 1) across brain areas and along lifespan, suggesting compensatory informational mechanisms in brain networks, that as far as we know, never before has been acknowledged. Future research should pay attention to what possible mechanisms or circuits can sustain R and S in the brain.

Lifespan Development:

Aging [2]

Modeling and Analysis Methods:

fMRI Connectivity and Network Modeling [1]
Task-Independent and Resting-State Analysis

Keywords:

Aging
FUNCTIONAL MRI
Other - Redundancy

[1|2]Indicates the priority used for review