ID: 1385

Prefrontal brain connectivity reorganization after traumatic brain injury

TAKE AWAY

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INTRODUCTION

Traumatic brain injury (TBI) affects its structural connectivity, triggering the re-organization of structural-functional circuits in a manner that remains poorly understood.

Over the past decades imaging techniques such as diffusion weighted imaging (DWI) and functional Magnetic Resonance Imaging (fMRI) have progressed our understanding of the physiopathology of TBI (see [1] and references therein).

We hypothesize that when structural networks are damaged after TBI, a reorganization in the corresponding functional networks must exist, and vice versa, in concordance with previous work showing the closed-loop relation between brain structure and function [2].

We use an atlas that is rooted on a common structure-function skeleton [2], such that voxels belonging to the same region in the atlas have homogeneous dynamics and, at the same time, are structurally wired.

METHODS

27 Controls. Age: 15.04 ± 2.26 years. 12 males, 15 females.

14 TBI patients. Age: 13.14 ± 3.25 years. 6 males, 8 females.

Average age at the time of injury: 10 ± 2.26 years.
Time between injury and the imaging session: 3.5 years on average.

Same subject triple-acquisitions: anatomy (T1), diffusion tensor imaging and resting T2* functional imaging where acquired with a 3T Magnetom Trio MRI scanner (Siemens) with a 12channel matrix head coil. Whilst the T1 was mainly used for preprocessing and coregistration, diffusion tensor imaging provided structural networks of white matter between brain areas, and variations in the blood oxygenation level dependent T2* signal provided functional networks.

A new hierarchical atlas in which regions are functionally coherent and at the same time structurally integrated was used for the analysis[2].

The study was approved by the KU Leuven Ethics Committee for biomedical research (Principal Investigator: Stephan P. Swinnen).

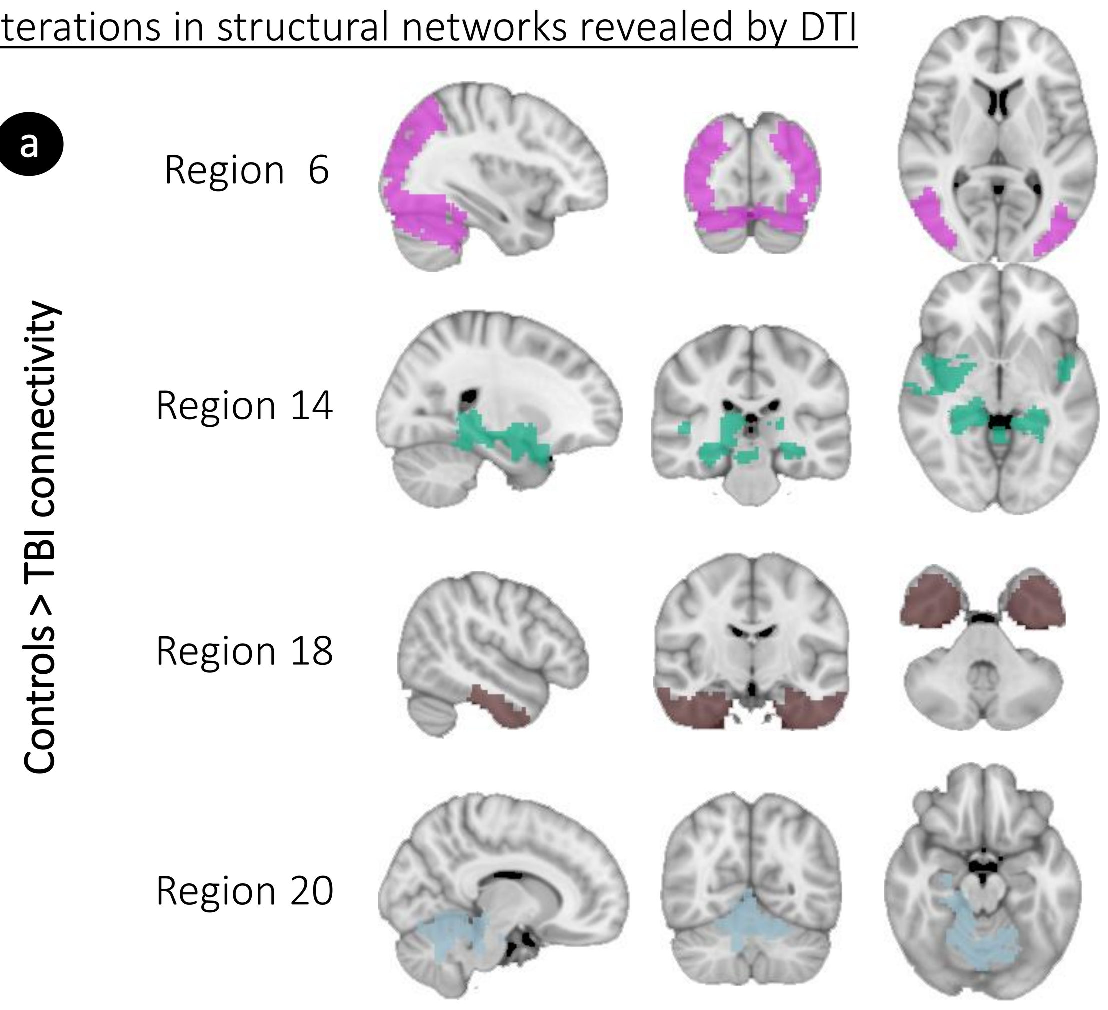
ID	Age	Gender	Cause of injury	Age at injury	Time since injury	GCS/Coma duration
T01	8.6	M	TA	7.9	0.7	C: 5days
T02	18.1	F	TA	15.6	2.5	C: 5days
T03	9.3	F	TA	7.9	1.4	C: 2weeks
T04	16.5	F	TA	7.2	9.3	NA
T05	14.2	F	TA	7.7	6.5	NA
T06	13.4	M	TA	12.5	0.8	NA
T07	19.0	F	Fall	12.5	6.5	NA
T08	15.6	M	TA	12.5	3.2	C: 10days
T09	13.9	M	TA	13.5	0.3	GCS: 3
T10	8.5	F	TA	7.7	0.8	NA
T11	11.4	M	Sport injury	9.8	1.5	NA
T12	13.3	M	TA	12.1	1.2	NA
T13	16.0	F	TA	NA	NA	NA
T14	13.8	F	Object Impact	3.0	10.8	NA

TA: Traffic Accident; C: Coma; ; GCS: Glasgow Coma Scale;
NA: Information not available; M: male; F: female

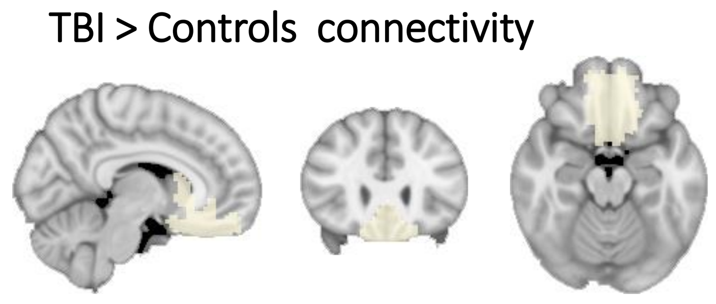
RESULTS

TBI alterations in structural networks revealed by DTI

a

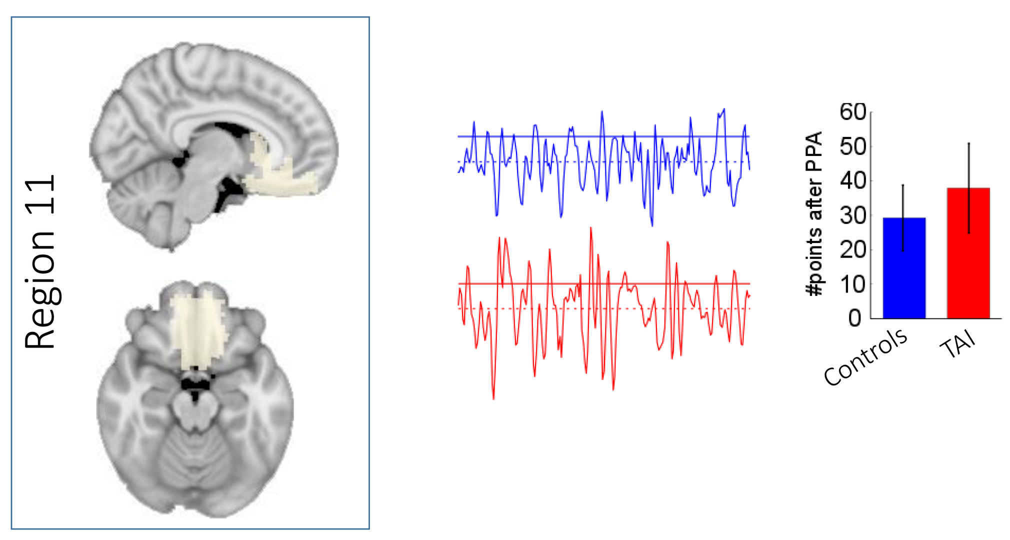


TBI > Controls connectivity



a Alterations in structural networks were assessed by calculating the connectivity degree for each region in the hierarchical atlas from the inter-region connectivity matrix and performing a group comparison (after correcting for multiple comparisons by performing random permutations in the structural connectivity matrix). A global decrease in connectivity associated with TBI was found and increased in orbitofrontal region.

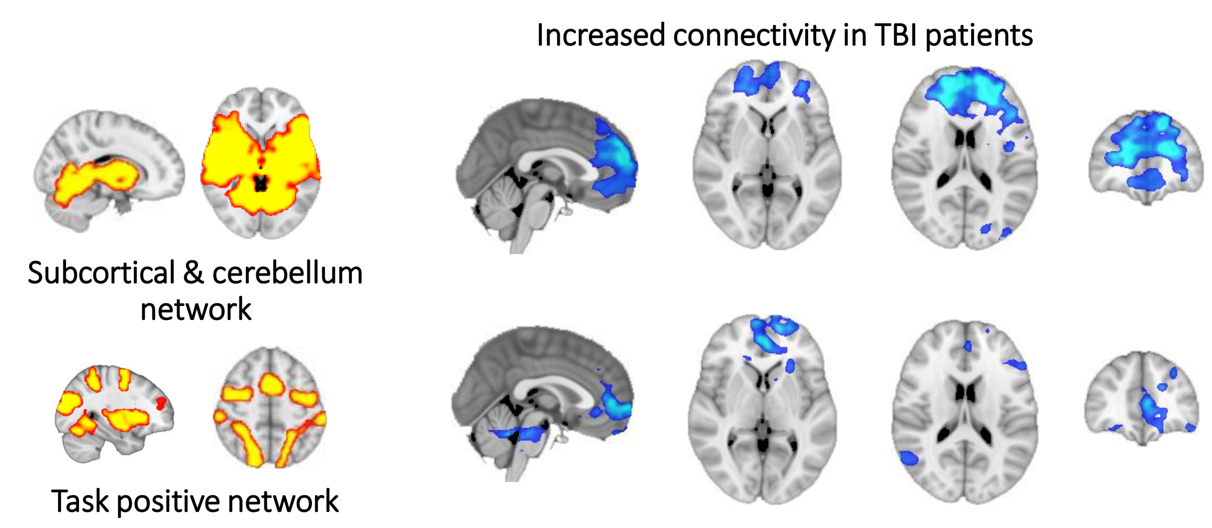
b TBI alterations in resting state functional MRI dynamics



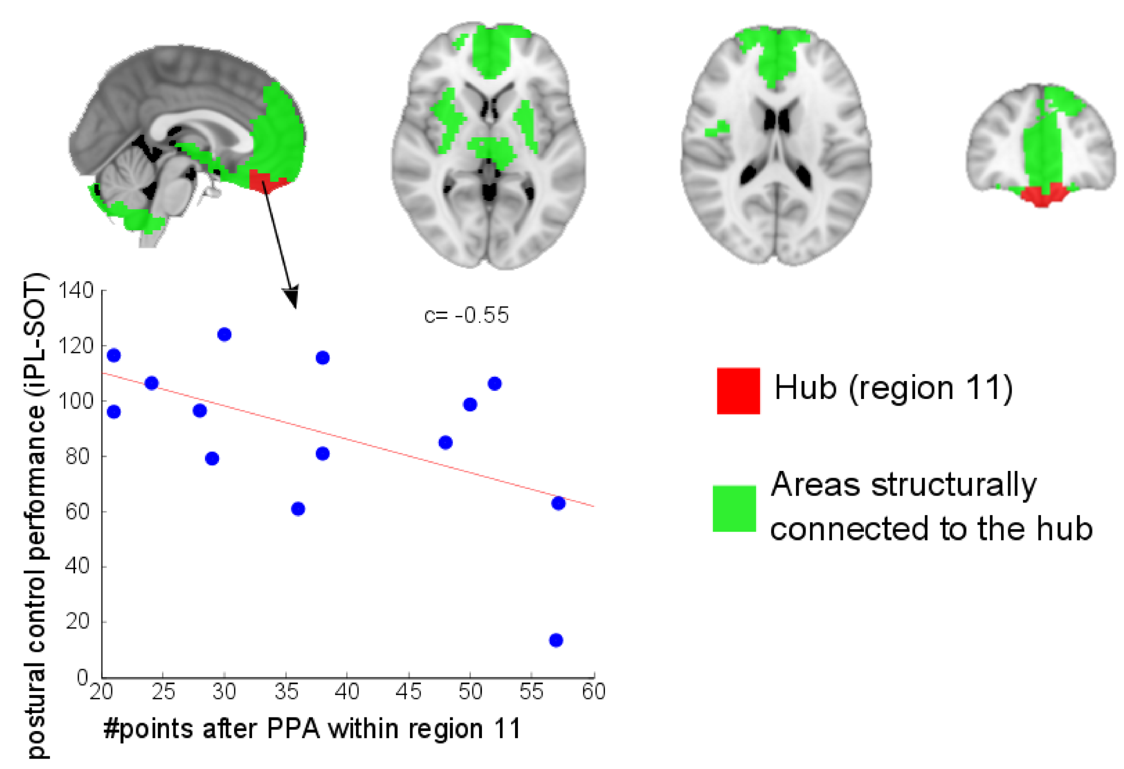
Alterations in the resting state brain dynamics were found in TBI patients in orbitofrontal regions. The number of time-series points that had a value above the mean value of the time series plus 1 times the standard deviation (Point Process Analysis, [3]) showed an increased activity in orbitofrontal regions of TBI patients.

c Quantifying the interaction from each regions to the rest of the brain an increased connectivity of prefrontal regions was found in TBI patients when interacting with both task positive network and subcortical and cerebellum network.

c TBI alterations in the interaction of resting state functional networks



Correlational analyses revealed that the activation at rest of region 11, represented by a high number of points after PPA, was related to the inverse path-length score of the static SOT test (iPL-SOT; r = -0.55, p = 0.04) and the directional control score of the dynamic test (DC-RWS; r = -0.57, p = 0.03). These results suggest that a better balance performance is associated with decreased activation in region 11. For further details on iPL-SOT and DC-RWS tests see [4].



CONCLUSIONS

To the best of our knowledge, this is the first time that such neuroplasticity is demonstrated in TBI at the interface between structural-functional network connectivity. Furthermore, our approach is also unique in that this adaptive plasticity is related to a critical behavioral function (postural control), supporting its functional relevance.

We consider these results of huge importance as the enhanced prefrontal activation found in the patients may provide the structural scaffold for stronger cognitive control of certain behavioral functions, consistent with the observation that various motor tasks are performed less automatically following brain insults and that more cognitive control is associated with such tasks. Thus, these results shed light on a new generic type of compensatory plasticity at the network level that may have relevance for many other insults of the central nervous system.

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