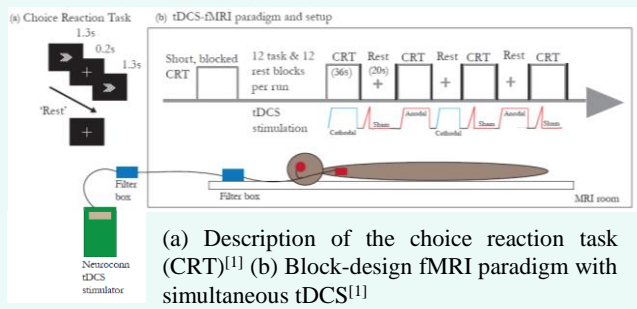# Investigating the interaction between white matter and brain state in tDCS-induced changes in brain network activity
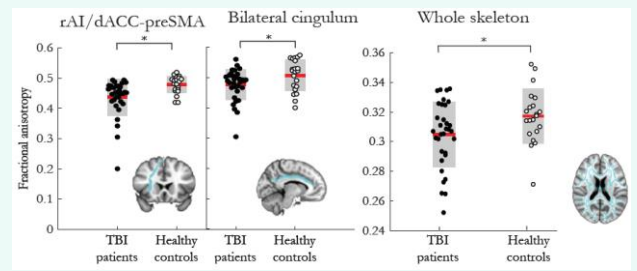
Brain state and WM structure determine the physiological effects of tDCS in traumatic brain injury (TBI) patients and healthy controls.

Danielle L. Kurtin, Ines R. Violante, Karl Zimmerman, Rob Leech, Adam Hampshire, Maneesh C. Patel, David W. Carmichael, David J. Sharp, Lucia M. Li
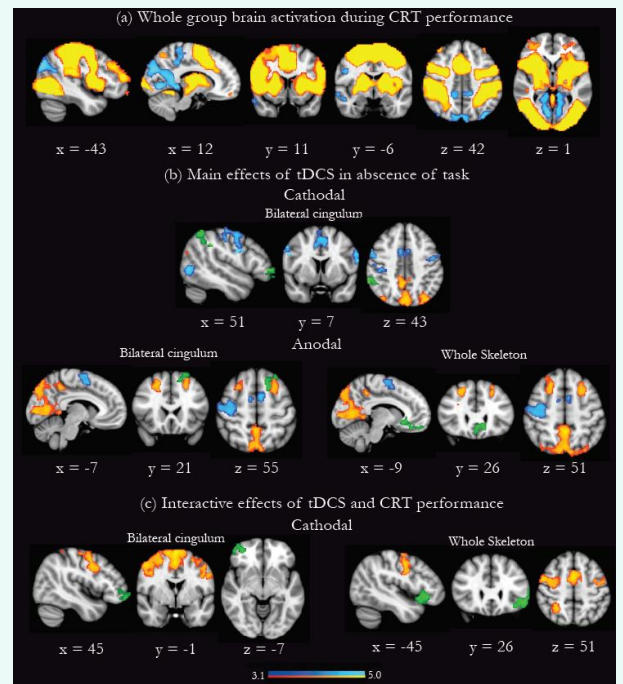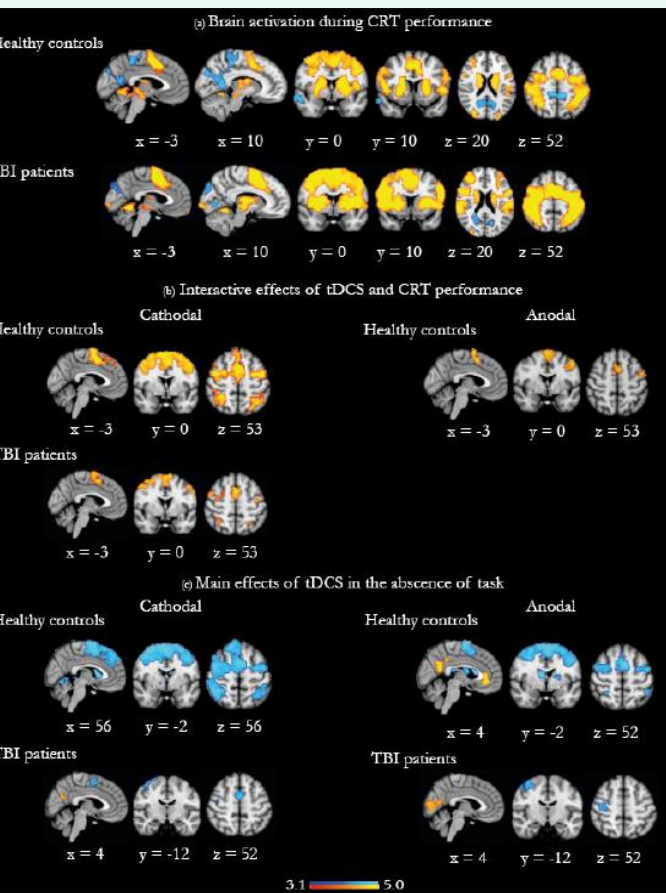
Imperial College London

C³NL

Experimental design

(a) Description of the choice reaction task (CRT)[1] (b) Block-design fMRI paradigm with simultaneous tDCS[1]

TBI patients have impaired white matter structure

Mean FA of TBI patients (in black) and healthy controls (in grey) for the rAI/dACC-preSMA, bilateral cingulum, and whole brain.

Replicating the brain state-dependent effects of TDCS in TBI patients

Brain activity in TBI patients and healthy controls. (a) Characteristic, state-specific network activity during CRT. (b) Interactive effects of cathodal stimulation during the CRT. (c) Anodal and cathodal effects in the absence of task.

White matter structure influences the brain state-dependent effects of tDCS on brain network activity in TBI patients and healthy controls

(a) State-specific network activity during CRT in TBI patients and healthy controls. (b) The influence of WM structure on anodal and cathodal effects in the absence of task (in green). (c) The influence of WM structure on the interactive effects of cathodal stimulation during the CRT (in green).

Introduction and Aims: TBI results in diffuse axonal injury, compromising the structural integrity of the brain, resulting in working memory, attentional, and cognitive deficits. These executive processes coincide with salience network (SN) activity [2]. Transcranial direct current stimulation (tDCS) is a method of noninvasive brain stimulation that modulates network-specific activity resulting in improved task performance in healthy controls. This improvement depends on measures of white matter integrity[2]. We aimed to characterize the influence WM structure has on the brain state and polarity dependent effects of tDCS. We hypothesized we would replicate our previous finding that brain state and stimulation polarity influence tDCS's effects on brain network activity in a cohort of TBI patients. We also hypothesize that WM structure also influences the physiological effects of tDCS, but that this influence interacts with the underlying brain state.

Methods: Thirty-five participants with moderate-severe TBI (5F:30M) and twenty-four healthy controls (12F:12M) were recruited; exclusion criteria was maintained as in Li et al 2019 [1]. Task paradigm, imaging (T1, fMRI) acquisition and preprocessing were conducted as described in Li et al 2019[1]; DWI procedures were conducted as described in Li et al 2019[2]. Analysis using FSL's FEAT constructed interactive regressors that interrogate the interactive effects between polarity and state.

Conclusions: 1) TBI patients have impaired WM structure as compared to healthy controls. 2) tDCS has network-specific state and polarity dependent effects in TBI patients. 3) WM structure influences the brain state-dependent effects of tDCS on brain network activity in TBI patients and healthy controls. We have shown interactions among these parameters influence the behavioral and physiological effects of tDCS. We speculate these interactions influence tDCS's mechanism of action. Studies that further investigate the interactions among the parameters of tDCS will develop a more complete mechanistic understanding, a step towards effective deployment of tDCS for research and clinical use

References:[1] Li, Lucia M., et al. "Brain state and polarity dependent modulation of brain networks by transcranial direct current stimulation. "Human brain mapping 40.3 (2019): 904-915.
[2] Li, Lucia M., et al. "Cognitive enhancement with Salience Network electrical stimulation is influenced by network structural connectivity." NeuroImage 185 (2019): 425-433.