Brain reorganization and cognitive functions recovery after stroke

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Main goal of the lab

Cognitive deficits following brain lesions are frequent and pervading. Recovery depends on neural plasticity, including major brain reorganization and the recruitment of additional neural networks. The mechanisms that underlie brain reorganization following therapeutic cognitive interventions are unknown. Moreover, biomarkers allowing to distinguish patients that will be good responders to specific interventions remain to be confirmed. Our lab aims to shed new light on the efficacy, mechanisms, and neural modulation brought by specific interventions targeting cognitive processing, in particular visual attention, working memory, and executive functions. Our studies focus currently on interventions using virtual reality, analyzing their effects by means of functional and anatomical neuroimaging, psychophysics, and machine learning.

The lab is situated in the Lausanne University Hospital (CHUV), in the Neuropsychology and Neurorehabilitation Service in the Clinical Neurosciences Department. Its location provides direct collaboration with the neurorehabilitation clinic allowing to carry out projects on patients with brain injury. Its long-term collaboration with the neuroimaging team provides the material and scientific resources to conduct strong and innovative studies on the functioning of the brain, in both patients and healthy subjects. The important advancement of new technologies opens exciting opportunities to develop brand-new therapeutic interventions and our collaborations with regional start-ups give us access to these new digital interventions, especially those using virtual reality. Our current funding will allow to conduct all of the neuroimaging acquisitions planned in this MD-PhD project.

Background of our projects

In a series of successful studies(1-10)leading to seminal publications we showed how a therapeutic intervention targeting attention deficit changes the organization of the brain regions involved in attention processing in healthy subjects (Figure 1A) and in stroke patients and age-matched healthy subjects (Figure 1B and C).

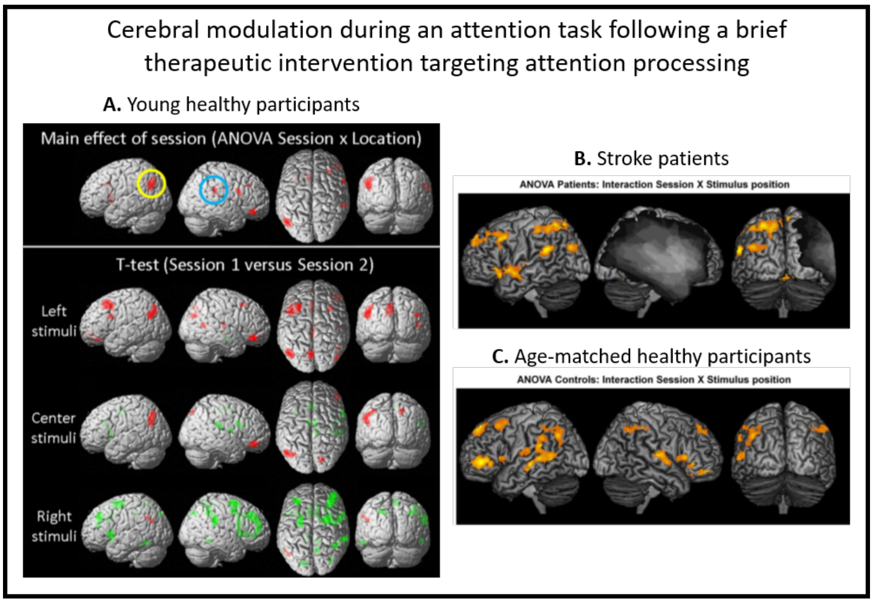

Figure 1: Cerebral modulation during an attention task following a brief neuropsychological intervention targeting attention processing in young healthy participants (part A, adapted from Crottaz-Herbette et al. 2014), in a group of 15 patients with stroke and in a group of healthy participants age-matched to the patients' group (respectively parts B and C, adapted from Crottaz-Herbette et al. 2017). Regions highlighted in red or orange: increases of activation after a session of prism adaptation. Regions highlighted in green: decreases of activation after a session of prism adaptation. For all groups, the activation was recorded while participants did a simple detection task of visual stimuli presented in the left, center or right visual fields during functional MRI acquisition. For details see the respective publications.

The therapeutic intervention used in these studies, called prism adaptation (PA), is one of the main methods used to alleviate spatial attention deficits in stroke patients. Our studies determined the mechanisms behind this intervention, and further provided biomarkers based on the location of the lesions, to determine patients who will be good responders to this intervention.

An important, but surprisingly under-explored, field in this domain concerns the dynamic interaction between brain networks in stroke patients, and how this interaction is modulated by therapeutic interventions. In healthy subjects (7; 10), we showed that the cognitive therapeutic intervention using prism adaptation changes the interplay between attentional networks (Figure 2). Attention deficits after stroke are known to be proportional to the disruption of the networks underlying attention, however, how therapeutic interventions change the interaction between these networks remains to be determined.

Cerebral modulation of attention networks following a brief therapeutic intervention on attention processing

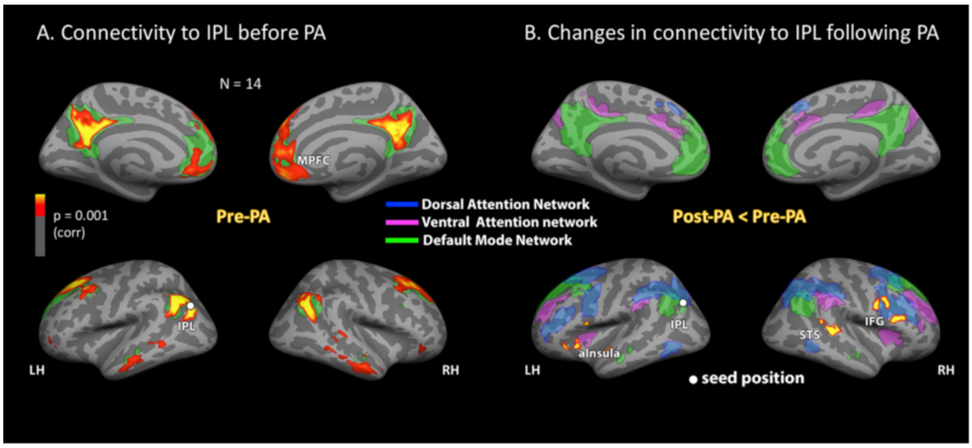

Figure2: Areas showing decreased connectivity to left inferior parietal lobule (IPL) following prism adaptation. (A) The map in yellow depicts functional connectivity to the seed area in the inferior parietal lobule (IPL) during the pre-PA resting state (B) The map in yellow depicts voxels that significantly reduced their connectivity to the seed region in the left IPL following LH: left hemisphere. RH: right hemisphere. See Wilf et al 2019 for more details

Proposed MD-PhD project

The proposed PhD project will be conducted in the field of cognitive neurosciences and cognitive neurorehabilitation. It will have a fundamental perspective, by investigating the mechanisms involved in cognitive processing in healthy subjects, and a clinical perspective, by examining the effects of new therapeutic interventions in patients with brain lesions, in particular those using virtual reality. These mechanisms will be studied using task-related and resting-state-related functional MRI acquisitions. Moreover, anatomy and fiber tracking will be examined to determine the impact of the damaged regions on the effects of the intervention, and to explore potential structural changes. The findings of this PhD project will allow to improve our understanding of the mechanisms underlying cognitive interventions and will optimize the indications of rehabilitation tools in neuropsychology by identifying which patients should be good responders to which interventions.

Ideal MD-PhD candidate profile

The ideal candidate has a master in neurosciences, cognitive psychology, biomedical engineering, computer science, physics, mathematics or a comparable degree, and interest in brain and cognitive functions. She/he will be expected to work independently and in a structured manner, be self-motivated, have good collaborative skills and have a great work capacity and enthusiasm for research. Affinity for data analysis, programming and machine learning is a plus but not a requirement. Knowledge of French is also a plus but not a requirement.

References

1. Crottaz-Herbette S, Fornari E, Clarke S. 2014. Prismatic adaptation changes visuospatial representation in the inferior parietal lobule. J Neurosci 34:11803-11
2. Crottaz-Herbette S, Fornari E, Notter MP, Bindschaedler C, Manzoni L, Clarke S. 2017. Reshaping the brain after stroke: The effect of prismatic adaptation in patients with right brain damage. Neuropsychologia 104:54-63
3. Clarke S, Crottaz-Herbette S. 2016. Modulation of visual attention by prismatic adaptation. Neuropsychologia92:31-41
4. Clarke S, Farron N, Crottaz-Herbette S. 2022. Choosing Sides: Impact of Prismatic Adaptation on the Lateralization of the Attentional System. Front Psychol13:909686
5. Crottaz-Herbette S, Fornari E, Tissieres I, Clarke S. 2017. A Brief Exposure to Leftward Prismatic Adaptation Enhances the Representation of the Ipsilateral, Right Visual Field in the Right Inferior Parietal Lobule. eNeuro 4
6. Crottaz-Herbette S, Tissieres I, Fornari E, Rapin PA, Clarke S. 2019. Remodelling the attentional system after left hemispheric stroke: Effect of leftward prismatic adaptation. Cortex 115:43-55
7. Gudmundsson L, Vohryzek J, Fornari E, Clarke S, Hagmann P, Crottaz-Herbette S. 2020. A brief exposure to rightward prismatic adaptation changes resting-state network characteristics of the ventral attentional system. PLoS One 15: e0234382
8. Tissieres I, Elamly M, Clarke S, Crottaz-Herbette S. 2017. For Better or Worse: The Effect of Prismatic Adaptation on Auditory Neglect. Neural Plast 2017:8721240
9. Tissieres I, Fornari E, Clarke S, Crottaz-Herbette S. 2018. Supramodal effect of rightward prismatic adaptation on spatial representations within the ventral attentional system. Brain Struct Funct 223:1459-71
10. Wilf M, Serino A, Clarke S, Crottaz-Herbette S. 2019. Prism adaptation enhances decoupling between the default mode network and the attentional networks. Neuroimage 200 : 210-20