 DOI: 10.3217/978-3-85125-962-9-11

Source Analysis of Directed Brain Connectivity During Opposite Neurofeedback Tasks

Ioana Susnoschi-Luca[1*], Aleksandra Vučković[1]

[1]*Centre for Rehabilitation Engineering, University of Glasgow, Glasgow, United Kingdom*

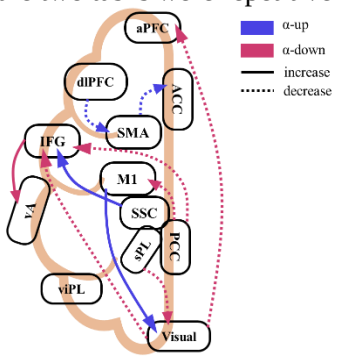
*E-mail: i.susnoschi-luca.1@research.gla.ac.uk

Introduction: Neurofeedback (NF) is a form of BCI based on operant conditioning. It can be used as a stand-alone intervention, to treat a variety of conditions or symptoms (e.g., anxiety, neuropathic pain), or training for assistive BCI devices [1]. One ubiquitous paradigm is alpha-power NF. To harness NF benefits, it is of utmost importance to deepen our understanding of externally (NF-) controlled brain dynamics. This study aims to compare directed connectivity changes and related mental strategies during NF for alpha upregulation (α-up) and downregulation (α-down).

Materials, Methods and Results:

22 able-bodied volunteers (age 27 ± 6, 7F) had three sessions of visual EEG-NF for alpha power modulation from electrode Cz, overlapping M1, the primary motor cortex (α-up n = 7; α-down n=15). The interface indicated power modulation as bars changing colour (green-red) and height. Participants revealed modulation strategies at the end of each session. Directed transfer function (DTF) was used to estimate frequency domain connectivity from sources reconstructed with sLORETA based on 64-channel EEG, between regions of interest selected a priori, spanning a NF network (NFN) [2], [3], the default mode (DMN) and frontoparietal networks (FPN), as indicated in Fig. 1.

Notable changes in alpha-band DTF (Fig. 1) include increased outflow from SSC to IFG and reduced connectivity between dlPFC-SMA-ACC in α-up, and decreased outflow from PCC and visual cortex during α-down. To achieve α-up, participants reported strategies based on mind clearing and breath focus, while for α-down, these were feedback- ("demand bar decreases"), planning- and emotion-related. Common to the two tasks were repetitive strategies (counting, mental arithmetic, focus on one word).



aPFC	- Anterior prefrontal cortex (DMN)
dlPFC	- Dorsolateral prefrontal cortex (DMN, FPN, NFN)
IFG	- Inferior frontal gyrus (FPN)
SMA	- Supplementary motor area (FPN, NFN)
ACC	- Anterior cingulate cortex (DMN, NFN)
M1	- Primary motor cortex
SSC	- Somatosensory cortex
vA	- Visual association area (NFN)
sPL	- Superior parietal lobule (FPN)
vIPL	- Ventral inferior parietal lobule (DMN)
PCC	- Posterior cingulate cortex (DMN)
Visual	- Visual cortex

Fig. 1 *- Directed connectivity in alpha band during NF compared to rest, blue- α-up, red- α-down tasks, and abbreviated regions of interest (assigned networks). Solid line = increase from rest, dotted line = decrease from rest, arrows point from source to sink.*

Discussion:

Relaxation strategies in α-up NF are reflected in reduced connectivity to IFG, the activity of which decreases with body relaxation, while increased outflow from SSC (adjacent to M1) points at attempted regulation of the target region. Decreased dlPFC to SMA connectivity might indicate efforts to relax and reduce mind-wandering. Reduction of PCC outflow (α-down) indicates undistracted concentration, and possibly more homogeneity of strategies in α-down NF compared to α-up. Information flow was reduced between FPN and both DMN and NFN in both tasks.

Significance:

Comparing connectivity in opposite NF tasks reveals brain network changes associated with NF processes in general, and those that are task specific. The changes reflect participants' mental strategies.

References:

[1]Q. Zhou *et al.*, "Neurofeedback Training of Alpha Relative Power Improves the Performance of Motor Imagery Brain-Computer Interface," *Front. Hum. Neurosci.*, vol. 16, 2022, doi: 10.3389/fnhum.2022.831995.

[2]K. Emmert *et al.*, "Meta-analysis of real-time fMRI neurofeedback studies using individual participant data: How is brain regulation mediated?," *Neuroimage*, vol. 124, pp. 806–812, 2016, doi: 10.1016/j.neuroimage.2015.09.042.

[3]M. Ninaus *et al.*, "Brain volumetry and self-regulation of brain activity relevant for neurofeedback," *Biol. Psychol.*, vol. 110, pp. 126–133, 2015, doi: 10.1016/j.biopsycho.2015.07.009.