a function could be compromised, resulting in problems in numerous activities of daily living. So far, there have been few studies aimed to analyze the effect of cognitive rehabilitation on attention improvement. In particular, no research has investigated whether the use of non-invasive brain stimulation associated with neuropsychological rehabilitation might contribute to a better and faster recovery of divided attention. Main purpose of this research is to assess the effectiveness of 10 tDCS sessions combined with a computerised training, aimed at improving divided attention in brain injured subjects. Specifically, we focused on the neural modifications induced by such a treatment. Sixteen subjects with a severe traumatic brain injury (Glasgow Coma Scale < 8) participated in the study. All participants were submitted to a neuropsychological evaluation one month prior to the beginning of the experiment (T_0). Such an evaluation was repeated the day before the training (T_1). In this occasion, each subject was also submitted to an fMRI session (MRI + divided attention paradigm). The training was characterised by 20' of tDCS, administered twice a day for 5 days. The electrodes were placed on the dorso-lateral prefrontal cortex, with the anode on the ipsilesional area and the cathode on the contralesional one. However, the specific electrode placement could vary for each patient depending on the location of the injury. After each session, the patient received 40' of a computerized cognitive training on divided attention. At the end of the treatment (T_2) TBI subjects were submitted to a third neuropsychological assessment, followed by a second fMRI session. Outcomes of the study highlighted an improvement of divided attention only between T_1 and T_2, resulting in faster reaction times ($p = .0001$), associated with decreased omissions ($p = .0001$). Furthermore, neuroimaging data resulted in a cerebral reorganization, associated with a lower cerebral activation following the training. In particular, a significantly lower activation in T_2 compared to T_1 was observed in right superior temporal gyrus (BA 42), right and left middle frontal gyrus (BA 6), right postcentral gyrus (BA 3) and left inferior frontal gyrus (BA 9). It follows that the cognitive and behavioral changes observed after our treatment may be related to modulations of neural plasticity. This neural reorganization may be explained as a sort of "balance mechanism": neural activations, which were wider and more generalized before the training, became more focal and task-specific after it.

Phantom learning: intermanual transfer of sequence learning in an amputee with phantom limb

Garbarini F. [1] **- Bisio A.** [2] **- Biggio M.** [1, 2] **- Pia L.** [1] **- Bove M.** [2]

[1] *SpAtial, Motor and Bodily Awareness Research Group (SAMBA), Department of Psychology, University of Turin, Turin, Italy*

[2] *Department of Experimental Medicine, Section of Human Physiology and Multifunctional Center of Sports Science, University of Genoa, Genoa, Italy*

Amputees who experience a phantom limb sometimes report that their phantom has certain sensory properties, like touch and pain, as well as kinesthetic properties, like being able to perform voluntary movements. Here, we focused on the motor domain and recruited one left upper-limb amputee (patient FC), who reported a vivid phantom limb and the ability to move it in a volitional manner. We asked whether the phantom movement go so far as leading to a motor learning, that, in turn, can be able to be transferred to the intact limb. To this aim, we took advantage from the intermanual transfer mechanism, that occurs when healthy subjects learn a motor skill with one hand and this results in performance improvement of the other hand as well. We tested patient FC and 10 aged-matched healthy controls, by using a sequence-learning task, in which the duration of the sequence execution was recorded with a sensor-engineered glove. The sequence duration was assumed as dependent variable to evaluate the ability to perform a fingers-thumb opposition sequence whit the right (intact) hand, before (naïve condition) and after a training with the left (phantom) hand. In the training phase, participants were asked either to actually execute the sequence (real condition) or to imagine it (imagery condition). The crucial aspect of this paradigm is that FC reported to be able to discriminate between the real and imagery training with her phantom. In healthy controls, results showed that, after a real training with the left hand, the ability to perform the sequence with the right hand was significantly improved with respect to the naïve condition (i.e., the sequence duration was significantly reduced). After the imagery training, no performance improvement was found (although the presence of a not significant tendency). Crucially, in FC, we found a significant performance improvement only after a "real" training with her phantom, suggesting the presence of an intermanual transfer. The first finding of the present study is that, in healthy subjects, an imagery training is not sufficient in order for the intermanual transfer to occur; a real motor learning seems to be necessary. In FC, we demonstrated that (a) volitional movements with a phantom limb can induce an intermanual transfer comparable to that evident in real movements; (b) motor execution and motor imagery with a phantom limb are functionally disentangled; (c) neural mechanisms underpinning the intermanual transfer continue to operate despite the prolonged absence of any proprioceptive or visual feedbacks. Converging evidence show that phantom limb is not "imaginary", but arises from physiological changes that occur after amputation. Here, we provided the first evidence that phantom limb can learn a motor skill and transfer it, through the callosal connections, to the intact limb.