Research Project: **The neural bases of action control in an emotional context**

Theoretical background

Swiftly halting ongoing motor actions is essential to react to unforeseen and potentially perilous circumstances. Interestingly, emotions elicited by the perception of arousing/threatening stimuli are likely to impact several cognitive functions, including action inhibition. The ability to inhibit prepotent responses can be explored through experimental investigation using a stop signal task (SST). From an operational point of view, participants are instructed to respond to a Go-stimulus and then promptly withhold their ongoing response when they encounter an occasional stop signal. The stop signal reaction time (SSRT), as conceptualized by Logan and Cowan (Logan et al., 1984) serves as an estimation of action inhibition performance. It quantifies the duration of the inhibitory process, revealing the time required for successful motor inhibition (i.e., longer SSRT indicates worse inhibitory performance). Indeed, several SST studies have demonstrated that emotions can influence action inhibition. However, they reported both enhancement (i.e., shorter SSRT) and impairment (i.e., longer SSRT) of action control by emotions (for a review, see Battaglia et al., 2021). Therefore, a great deal of confusion characterizes our understanding of the interplay between emotions and action control. Furthermore, the neural network subtending the interaction between emotion and action control has been scarcely investigated. As far as the potential neural responsible for the integration of action and the emotion processing one candidate is the action inhibition network (AIN). The AIN guides the voluntary inhibitory process during SST (with neutral stimuli) via the hyperdirect pathway connecting the inferior frontal cortex (IFC) and the supplementary motor complex (SMA, which includes the pre-SMA and SMAproper) to the subthalamic nucleus (STN). Yet, it is still a matter of debate whether and how these cortico-subthalamo-pallidal networks interface with the processing of emotional stimuli.

Aims and Hypotheses

Here we aim to investigate the neural bases of the interplay between action control and emotional stimuli. To address this issue, we will applied Transcranial Magnetic Stimulation (TMS) over different regions of the AIN. Previous results suggest that the SMA-complex, via direct afferents from the amygdaloid complex, could be the cortical hub interfacing the limbic and the motor systems. Thus, we expect the pre-SMA to be involved in action control in an emotional context, while the IFG to be mainly involved in action suppression in a neutral context (Sagaspe et al., 2011). No changes in action control are expected after having influenced the activity of the M1.

Methods

Participants: sample size and justification of the sample size

A power analysis based on previously published studies (Borgomaneri et al., 2020) indicates that a sample size of 15 participants is necessary to achieve a statistical power of > 95% (2-tailed = 0.05). Thus, 45 healthy volunteers will be tested in three different experiments (see the Procedure section).

Tools

To measure action inhibition we will use a widely used paradigm called Stop Signal Task (SST) that we have widely employed in our previous works (e.g., Battaglia et al., 2022). In this task, participants are requested to respond to a go stimulus (i.e., discriminating an arrow orientation). However, sometimes, the go stimulus is followed by a stop signal represented by a neutral or emotional stimulus that requires participants to withhold the ongoing action. To measure the participant's ability to withhold their actions, the stop-signal reaction time (SSRT), an index of reactive inhibition, will be computed. Estimated SSRT values will give the measure of the duration of the inhibitory process,

with a lower value indicating a more efficient action control. Transcranial Magnetic stimulation (TMS) will be applied to modulate target brain regions. Self-report questionnaires to assess participant's impulsivity (Barratt Impulsiveness Scale; BIS-11) (Patton et al., 1995) and anxiety (State-Trait Anxiety Inventory; Trait-scale-Y2) (Spielberger, 1983) will be administered.

Procedure

Participants will be asked to perform the Stop Signal Task before and after the administration of the TMS protocol. In Experiment 1, TMS will be applied over the pre-SMA. In Experiment 2, TMS will be applied over the IFC and in a third experiment over the primary motor cortex (M1) as an active control region. At the end of each experiment, participants will be asked to complete self-report questionnaires.

Statistical analyses

SSRT and reaction times (RTs) will be collected during the Stop Signal Task before and after the rTMS administration. Analysis of variance (ANOVA) will be used to investigate differences within and between groups. Post-hoc analyses will be conducted with Newman-Keuls test, and the significance threshold will be set at $p < 0.05$.

Declaration of commitment to request ethical approval

All procedures have been already approved by the Bioethical Committee at UNIBO, Prot. 0210065 del 27/7/2023.

Expected results and Implications

We expect to reduce the impact of the emotional stimuli on the action inhibition capabilities (i.e., longer SSRT for emotional stimuli) after having affected the neural activation of the pre-SMA and thus reducing its influence over M1. No effects are expected delivering TMS over IFC on the ability to control motor behavior facing emotional stimuli. Rather, it is possible to expect an effect when action control should be implemented in a neutral context. No specific emotion-related effects are expected after the stimulation of M1.

References

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Plan of activities

Research environment: the proposed project will be carried out at the Center for studies and research in Cognitive Neuroscience in Cesena.

Project activities: literature review to acquire relevant theoretical knowledge and to define stimulation parameters and behavioral procedures, recruitment of participants, execution of a pilot study to assess experimental duration and participant's compliance, data collection and analysis, writing of a draft of the main findings to be submitted to a scientific journal and research dissemination at national/international congresses.

Training activities: readings, discussions with the supervisor, direct involvement in lab meetings, attendance of lectures and workshops, revision of manuscripts; activities aimed at acquiring: 1) theoretical knowledge about key models and thematic areas related to cognitive neuroscience of action control; 2) skill for designing and conducting scientific research projects, data analysis and use of non-invasive brain stimulation procedures; 3) writing and oral communication skills for scientific dissemination.

Timing of activities: literature search designing and piloting (Feb 2024 – May 2024); Data collection and analysis (May 2024 – Dec 2024); Dissemination (Sept 2024 – Feb 2025).

Feasibility of the project: the project is highly feasible and involves low risks. The supervisor have acquired extensive expertise on the methods and have already conducted several studies using TMS. Procedures have been already approved by the ethical committee at UNIBO. All the tools and research materials have been already acquired. Based on previous studies we predict mid/large effect sizes; therefore, an adequate sample can be acquired in less than 7 months.