Research Project: **The complex interplay between emotions and actions and its neural mechanisms**

Theoretical background

The complexity of human sociocognitive architecture makes the distinction between what is the appropriate action and what is not a rather subtle task of its own. Emotions contribute significantly to this fuzziness and often play a causal role in undermining our best judgment. Yet, the neurobehavioral mechanisms that interface action control and emotional processing are largely unknown and represent a modern scientific challenge. While cognitive control processes are typically associated with consciousness, a significant amount of processing can take place unconsciously, influencing behavior. Although the influence of non-conscious stimuli on motor responses has been established (Engelen et al., 2018), the role of emotional awareness in controlling actions remains unclear. Additionally, studies have suggested that the capacity for action control in a neutral context can be anticipated by indices of GABAergic inhibition (He et al., 2019). However, the examination of corticocortical indices of action excitation/inhibition in the context of action control with unconsciously presented emotional stimuli has not yet been explored. To unravel the interplay between emotional awareness and its neurophysiological underpinnings concerning the balance of motor excitation/inhibition, it becomes crucial to investigate. This exploration would enable the identification of key neurobehavioral processes and measures, paving the way for therapeutic interventions in clinical and psychiatric populations.

Aims and Hypotheses

The present project aims to shed light on the complex interplay between action control and emotional stimuli. First, we will investigate the role of perceptual awareness on action inhibition. Then, Transcranial Magnetic Stimulation (TMS)-based indexes of corticospinal GABAergic inhibition (SICI) and glutamatergic facilitation (ICF) will reveal how low-level neurophysiological measures (i.e., excitation/inhibition balance) map to behavior at the single-subject level with the scope of deriving an objective biomarker of action inhibition performance while concurrently processing emotions.

Methods

Participants: sample size and justification of the sample size

A power analysis based on previously published studies (Borgomaneri et al., 2015) indicates that a sample size of 14 participants is necessary to achieve a statistical power of > 95% (2-tailed = 0.05). Thus, 30 healthy volunteers will be tested in the first behavioral experiment and other 14 participants will be tested in a second neurophysiological experiment (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 stimulus (i.e., crosses) that requires participants to withhold the ongoing action. Before the arrows, participants will be presented with emotional or neutral body postures as prime stimuli. 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. To test neurophysiological measures of intracortical and corticospinal excitability, we will record motor-evoked potentials (MEPs) as well as measures of short intracortical inhibition (SICI) and intracortical facilitation (ICF) as in our previous work (e.g., Borgomaneri et al., 2015). Self-report questionnaires to assess participant's impulsivity (Barratt Impulsiveness Scale; BIS-11) (Patton et al., 1995), anxiety (State-Trait Anxiety Inventory; Trait-scale-Y2) (Spielberger, 1983) and the tendency to freeze action when facing potential threats (the BIS/BAS) (Carver & White, 1994) will be administered.

Procedure

In Experiment 1, participants will be asked to perform the SST. In Experiment 2, participants will be asked to complete the SST and participants' indices of cortical and corticospinal excitability will be recorded at rest, such as the motor-evoked potentials (MEPs), the short intracortical inhibition (SICI) and the intracortical facilitation (ICF). All participants will be asked to complete the questionnaires at the end of the experimental session.

Statistical analyses

SSRT and reaction times (RTs) will be collected during the Stop Signal Task while MEPs will be collected during the neurophysiological testing part of Experiment 2. Analysis of variance (ANOVA) will be used to investigate possible differences between stimuli. Post-hoc analyses will be conducted with Newman-Keuls test, and the significance threshold will be set at $p < 0.05$. Correlational indices will be used to compare the behavioural (i.e., SSRT) and the neurophysiological indices (i.e., MEPs amplitudes).

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

Due to the ability of emotional stimuli to impact motor excitability even when unconsciously presented (Engelen et al., 2018), we should observe a similar reduction of SSRT when fearful stimuli are presented (Battaglia et al., 2022), even if unconsciously perceived. Moreover, we expect individual differences selectively in SICI to be positively associated with relevant performance metrics on the SST, in line with similar evidence testing neutral, non-emotional conditions (He et al., 2019). No effects are expected with ICF indices.

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.