A causal account of the brain network computations underlying strategic social behavior

Author: Christian Ruff

Group Members:

Lailumah Hiba Nadeem (20K-0431)
Fabiha Attique (20K-0369)
Naima Jamal (20K-0404)

Background

Competition is a common aspect of human interactions, and success often depends on predicting the actions of competitors. Strategic decision-making involves mentalizing, which is the ability to understand and simulate the beliefs and intentions of others. Previous research has linked the temporoparietal junction (TPJ) to **mentalizing** processes and shown that neural activity in this region correlates with strategic behavior. However, it remains unclear whether the computations in the TPJ are causally related to strategic decision-making.

Executive Summary

- Study investigates neural computations in the **right temporoparietal junction (rTPJ)** and interconnected brain structures in strategic social behavior.
- Utilizes inhibitory **continuous theta-burst transcranial magnetic stimulation (cTBS)** and **model-based functional MRI.**
- Findings show disrupting neural excitability in rTPJ affects mentalizing-related computations and functional connectivity in the brain.
- Results establish causal relationship between rTPJ computations and integration of opponent beliefs in strategic decision-making.

Before beginning with the methodology, we need to understand some key terminologies

- **rTPJ (right temporoparietal junction):** A brain region associated with mentalizing and understanding others' beliefs and intentions in social cognition.
- **fMRI (functional Magnetic Resonance Imaging):** A neuroimaging technique that measures brain activity by detecting changes in blood flow, allowing researchers to observe brain function in real-time.
- **rTMS (repetitive Transcranial Magnetic Stimulation):** A non-invasive brain stimulation technique that uses magnetic fields to induce electrical currents in specific areas of the brain, modulating neural activity.
- **cTBS (continuous Theta-Burst Transcranial Magnetic Stimulation):** A variant of rTMS that delivers magnetic pulses in a specific pattern, often used to temporarily disrupt neural activity in targeted brain regions.

Before beginning with the methodology, we need to understand some key terminologies

- **dmPFC (dorsomedial prefrontal cortex):** A brain region involved in social cognition, theory of mind, and self-awareness.
- **vmPFC (ventromedial prefrontal cortex):** A brain region implicated in emotional regulation, reward processing, and decision-making based on value assessments.

Methodology

- Participants: A total of 120 healthy subjects (60 females) participated in the experiment. Their ages ranged from 18 to 25 years.
- Experimental Design: The study employed a competitive game called the **inspection game**, which involved two players and a 2x2 strategy space with asymmetric payoffs. The game required participants to predict and respond to their opponent's behavior. One group of participants underwent inhibitory continuous theta-burst transcranial magnetic stimulation (cTBS) over the right temporoparietal junction (rTPJ), while the other group received cTBS over a vertex control site to account for nonspecific effects.

Methodology

- Functional Magnetic Resonance Imaging (**fMRI**): Participants underwent fMRI scanning while playing the inspection game. fMRI measures changes in blood-oxygen-level-dependent (**BOLD**) signals, which reflect neural activity in different brain regions.
- Computational Model: The study employed a computational model that captured the participants' behavior and mentalizing processes during the game. ***The model distinguished between first-order beliefs (how players react to opponents' past choices) and second-order beliefs (what players thought their own actions would make their opponents do)***.

Methodology

- Comparison: They compared the group that received rTPJ cTBS with the control group that received vertex cTBS.
- The study examined functional connectivity between the rTPJ and other brain regions, specifically the dorsomedial prefrontal cortex (dmPFC) and ventromedial prefrontal cortex (vmPFC).
- Statistical Analysis: The data were analyzed using statistical methods, including hierarchical **Bayesian model estimation procedures**, to assess the effects of rTPJ stimulation on behavior and neural activity.

Experiments and Results

In the conducted experiments, a combination of functional MRI (fMRI) and repetitive transcranial magnetic stimulation (rTMS) was employed. Specifically, inhibitory continuous theta-burst transcranial magnetic stimulation (cTBS) was applied to the right temporoparietal junction (rTPJ) and a vertex control site. Two groups of participants were studied: the rTPJ cTBS group and the control group.

The behavioral results revealed that participants in the rTPJ cTBS group exhibited decreased strategic behavior compared to the control group. They struggled to accurately estimate the impact of their own actions on their opponent's future behavior, indicating impaired mentalizing-related processes.

Experiments and Results

When the excitability of the rTPJ was disrupted, the neural activity in this brain region decreased. This reduction in neural activity specifically affected the computation of the influence signal, which is important for understanding the impact of one's own actions on the opponent's behavior. Additionally, there was a decrease in the connectivity between the rTPJ and the dmPFC, another brain region involved in decision-making. Interestingly, there were signs that the dmPFC may have tried to compensate for the disrupted rTPJ activity. Furthermore, the disruption of rTPJ excitability also influenced how the vmPFC, a region associated with value computations, functioned by altering its connectivity with other brain regions.

Experiments and Results

In summary, the experiments provided evidence supporting the causal role of neural computations in the rTPJ in strategic social behavior. The disruption of rTPJ excitability led to decreased strategic behavior, impaired mentalizing-related processes, reduced neural activity associated with the influence signal, and altered functional connectivity between the rTPJ and other brain regions. These findings underscored the significance of the rTPJ and interconnected brain networks in the integration of opponent beliefs and the execution of strategic choices.

Key Findings

- Disrupting Neural Excitability in rTPJ: Inhibitory cTBS applied to the rTPJ significantly influenced mentalizing-related computations and functional connectivity within the brain.
- Establishing Causal Relationship: The results provided evidence of a causal relationship between the computations in the rTPJ and the integration of opponent beliefs in strategic decision-making.
- Neural Correlates of Strategic Behavior: The fMRI data unveiled distinct neural activation patterns in the rTPJ and its connectivity with the dmPFC and vmPFC during the inspection game, highlighting their involvement in strategic social behavior.
- Computational Model Validation: The computational model effectively captured participants' strategic behavior and mentalizing processes, reinforcing the role of the rTPJ in decision-making.

Key Discussion Points

- Role of the right temporoparietal junction (rTPJ)
- Neural computations and strategic decision-making
- Functional relevance of neural computations
- Interactions between the rTPJ and other interconnected brain regions

Limitations

- Temporary disruption: The use of inhibitory cTBS provides only a temporary disruption of neural activity in the rTPJ.
- Generalizability: The study focused on a specific participant sample and task context.
- Specificity of cTBS effects: The effects of inhibitory cTBS are not specific to the rTPJ alone.
- Contextual limitations: The study examined competitive social interactions, and the role of the rTPJ may vary in different social contexts.
- Causality and alternative explanations: While the study establishes a causal link between the rTPJ and strategic decision-making, alternative explanations and confounding factors cannot be entirely ruled out.

Any questions?