Dissecting functional contributions of the social brain to strategic behavior

Arkady Konovalov, Christopher Hill, Jean Daunizeau, Christian C. Ruff

Neuron, 20 October 2021

Group Members

- Abdul Ahad Shaikh (20K-0319)
- Mohammad Basil Ali Khan (20K-0477)
- Muhammad Umer (20K-0225)

Contents

Executive Summary

- Comprehensive investigation into neural mechanisms of strategic decision-making in social contexts
- Utilization of behavioral experiments and fMRI to explore brain processing of social cues
- Enhanced performance observed in social interactions, especially against reactive opponents
- Importance of theory of mind (ToM) and social cognition in decision-making highlighted
- Neuroimaging reveals distinct activation patterns in social brain network, with TPJ and dmPFC implicated

Executive Summary

- dmPFC identified as crucial for top-down control of strategic behavior
- Discussion on potential clinical implications for disorders like autism spectrum disorder
- Exploration of link between environmental reactivity perception and social interpretation, including implications for conditions like gambling addiction
- Overall, research provides valuable insights into complex relationship between social cognition and decision-making, with implications for both clinical and societal contexts

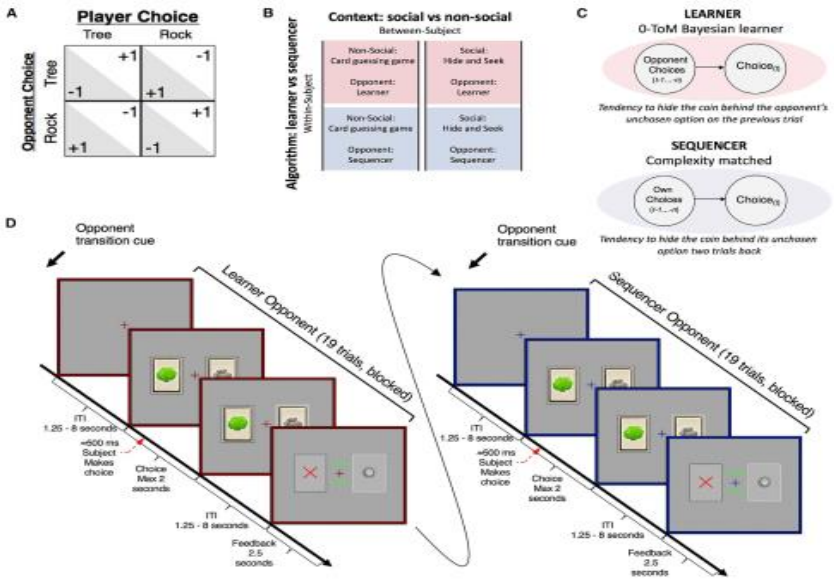
Background

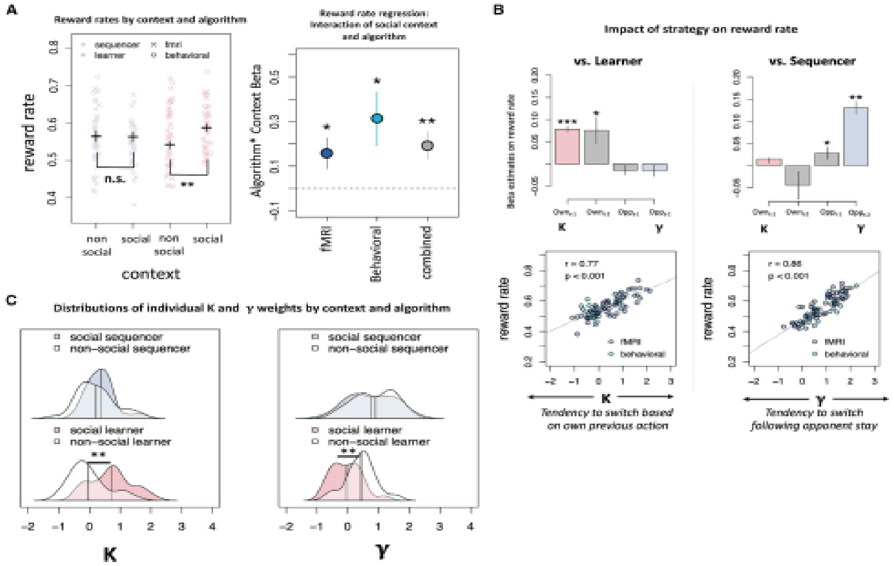
- Intersection of neuroscience, psychology, and social cognition
- Interest in strategic decision-making in social contexts
- Humans possess theory of mind (ToM) for understanding others' behavior
- ToM crucial for social interactions and strategic decision-making
- Neuroimaging techniques like fMRI used to study brain activity
- Brain regions implicated in social behaviors: TPJ, dmPFC, precuneus
- Questions remain on how social brain contributes to strategic behavior

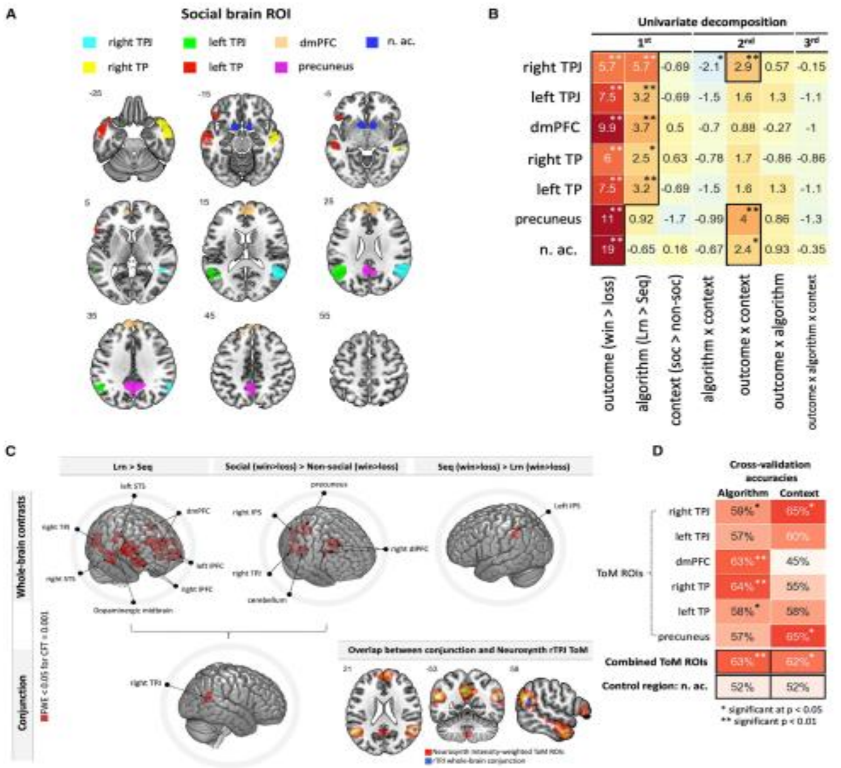
Background

- Article employs multidisciplinary approach:
- Behavioral experiments
- Computational modeling
- Neuroimaging analyses
- Aims to dissect functional contributions of social brain network
- Seeks to understand neural processes underlying strategic decision-making in social contexts
- Implications for understanding human social behavior and its disorders

Experiments and Results







Behavior: Context cues strategy use

Main Findings

- Participants performed better in the social context against a reactive opponent compared to a non-reactive opponent.
- Performance against the non-reactive opponent remained consistent across social and non-social contexts.
- Optimal strategies were identified for each opponent type, and participants' choices closely aligned with these strategies.
- Subjects relied more on second-order beliefs in social contexts, leading to improved performance against the reactive opponent.

Implications:

- The presence of a social context prompts specific cognitive strategies, potentially mediated by neural processes in the social brain network.

fMRI: Activity in the social brain reflects both context and algorithm type

Main Findings:

- Social brain regions exhibited stronger activation when participants played against a reactive (learner) versus non-reactive (sequencer) opponent.
- The response profile varied across regions, with rTPJ showing a unique pattern indicative of both social context and algorithm interaction.
- Out-of-sample machine learning analysis confirmed that outcome-related activity in the social brain contained information about both context and opponent algorithm.

Implications:

- The social brain network is engaged in processing the reactivity of the environment during strategic interactions.
- The rTPJ may play a special role in cuing computational strategies based on social context.

fMRI: Activity in the social brain network reflects distinct computational specialization

Main Findings:

- RPE was encoded across all social brain regions, with a significant difference in the precuneus between social and non-social contexts.
- APE showed dissociation between regions, with dmPFC more involved in non-social contexts and precuneus in social contexts.
- Reactivity measure correlated with rTPJ activity, particularly in the non-social context, suggesting sensitivity to surprising reactivity.
- Choice value update correlated with nucleus accumbens activity, indicating involvement in reinforcement learning processes.

Implications:

- dmPFC is implicated in implementing strategies to predict opponent actions, while rTPJ is specialized in signaling opponent reactivity, especially in social contexts.
- Neural computations in the social brain network relate to the incorporation of second-order beliefs into behavior during strategic interactions.

fMRI: The rTPJ shows stronger functional coupling with reward regions when playing against reactive

Main Findings

- Increased connectivity with rTPJ observed for most social-brain regions during win versus loss outcomes, including dmPFC and rTP, independent of algorithm type and context.
- rTPJ showed differential connectivity with nucleus accumbens when winning versus losing against a learner opponent, primarily driven by loss outcomes.

Implications

- Tight integration in the social brain network, with rTPJ communicating behaviorally relevant outcome information to interconnected areas.
- Specific communication between rTPJ and nucleus accumbens may reflect the need to update mentalizing-based predictions of opponent choices, particularly after loss outcomes.

Methodology

- **Participants:**
- 60 participants took part in the fMRI study.
- Additional pilot behavioral data involved 20 participants.
- **Experimental Design:**
- Participants engaged in a game of matching pennies.
- The game was framed to involve either:
- Interacting with a human opponent (social context; n = 31).
- Interacting with a virtual card deck (non-social context; n = 29).
- Opponents were simulated by computer-generated algorithms:
- A reactive "learner" responding to the participant's choices.
- A non-reactive "sequencer" producing predetermined sequences.

Methodology

- **<u>Task</u>**:
- Participants made repeated strategic choices.
- Choices were matched across various dimensions but varied in social context and opponent reactivity.
- **<u>Data Collection:</u>**
- Blood-oxygen-level-dependent (BOLD) activity was measured using fMRI during task performance.

Methodology

- **Analysis:**
- Researchers looked at how players' choices differed in social and non-social games.
- They used computer programs to understand players' decision-making strategies.
- They compared players' actual choices with what the computer programs predicted.
- They checked if players' success in the game was related to how well they used different strategies.
- **Software and Algorithms:**
- Utilized various software tools and algorithms for data processing and analysis, including MATLAB, SPM12, CONN toolbox, and others.

Key Findings

1. **Social Brain Response**:
   1. Areas of the brain involved in social interactions respond not only to interactions with other people but also to non-social situations where there's a reaction from the environment.

2. **Role of TPJ**:
   1. The temporoparietal junction (TPJ), a brain area, mainly processes outcomes based on the situation and detects reactions from the environment.

3. **dmPFC Function**:
   1. Another brain area called the dorsomedial prefrontal cortex (dmPFC) helps in putting strategies into action.

4. **Overall Insight**:
   1. The study gives us a better understanding of how the social brain network works in different situations.

5. **Specialized Roles**:
   1. Different parts of the social brain network may have specific jobs in dealing with both social and non-social interactions.

Key Discussion Points

- **Social Brain Involvement:**
- The study suggests that the part of our brain responsible for social interactions doesn't just work when we're dealing with people. It also kicks in when we're reacting to things that aren't alive.
- **Understanding Strategic Behavior:**
- This research helps us better understand how our brains work when we're making strategic decisions in social situations.
- **Complex Brain Regions:**
- The study shows that the areas of our brain involved in understanding social situations and making decisions are really complicated. They do more than we thought.
- **Implications for Theories:**
- These findings can change the way we think about how our brains handle social situations and make decisions in different situations.
- **New Perspective on Social Brain:**
- The study gives us a fresh way of looking at how our brains help us behave strategically in social settings..

Limitations

1. **Sample Size**: The study involved a relatively small sample size of 20 subjects for the behavioral study and 66 healthy volunteers for the fMRI experiment, which may limit the generalizability of the findings.
2. **Generalizability**: The findings may be specific to the tasks and conditions used in the study, and caution should be exercised when extrapolating the results to broader social interactions.
3. **Task Complexity**: The strategic game paradigm used in the study may not fully capture the complexity of real-world social interactions, potentially limiting the ecological validity of the findings.
4. **Exclusion Criteria**: The criteria for excluding subjects based on performance and data quality may introduce bias and affect the representativeness of the sample.
5. **Neuroimaging Techniques**: While fMRI provides valuable insights into brain activity, it has limitations in spatial and temporal resolution, which may impact the interpretation of neural responses.

ANY QUESTIONS?