TUS of the human rmPFC and precuneus differentially modulate decision making in private and social contexts

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Introduction

Both the **medial prefrontal cortex** (mPFC) and the **precuneus** play important roles in **value-based decision-making**. The mPFC is involved in the computation of option values, incorporating **counterfactual signals and associated anticipated regret into decisions-making** processes[1,2,3]**.** The precuneus is involved in **reward processing**[4].

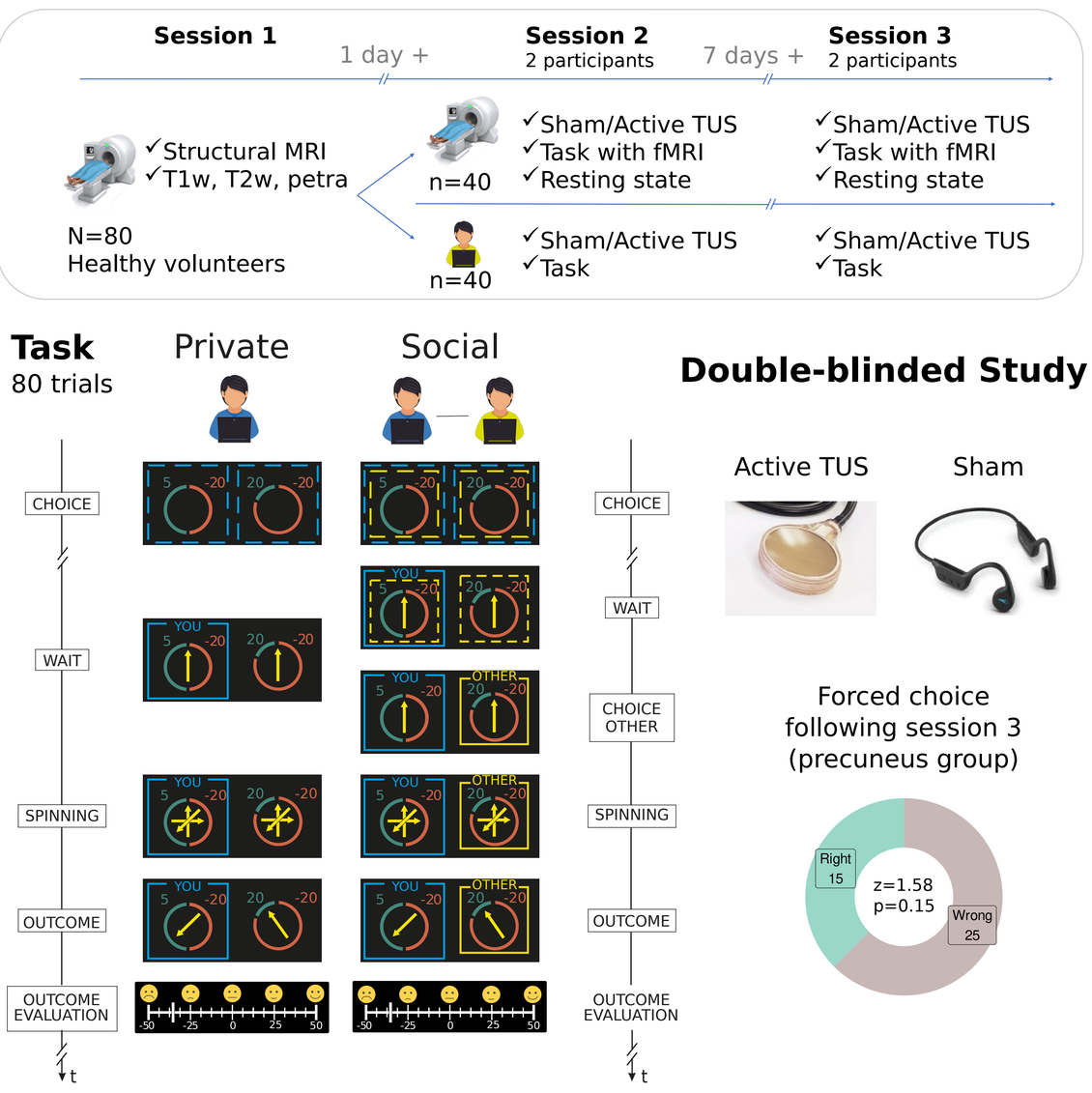
The rostral portion of the mPFC and the precuneus exhibit increased activity during **decision-making in the presence of others**[2,5]. This increased activity has been linked to the role of social comparision in modulating choice behaviour and hedonic reponses to reward. However, the specificity of these regions' roles in processing social signals remains a topic of debate[6].

Question:
What is the **causal role of the rmPFC and precuneus in processing value-related signals in private and social contexts**?

Hypotheses:
• Disrupting the activity of the rmPFC will modify the integration of decision variables, including expected value, risk, and counterfactual signals, into the choice process.
• Disrupting the activity of the precuneus will modulate responses to positive and negative outcomes.
• The effect of TUS in the processing of counterfactual signals will be more pronounced in social settings.

Methods

Procedure



Task
80 trials

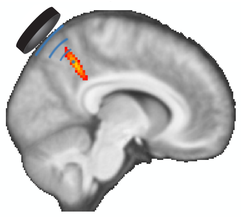
Double-blinded Study

Forced choice following session 3 (precuneus group)

Transcranial Ultrasound Stimulation Protocol

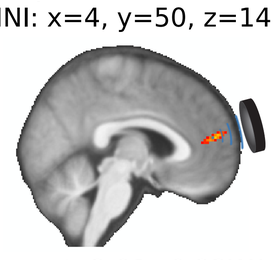
400 bursts, Pulse Duration = 20ms, Pulse Repetition Frequency = 5Hz, Stimulation Duration = 80s, Driving Frequency = 500kHz. Protocol from ref [7]

Group 1: Precuneus (N=40)
MNI: x=9, y=-48, z=42

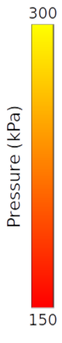


I_{sppa} target: 3.44±0.40W/cm^2

Group 2: rmPFC (N=40)
MNI: x=4, y=50, z=14



I_{sppa} target: 2.91±0.23W/cm^2



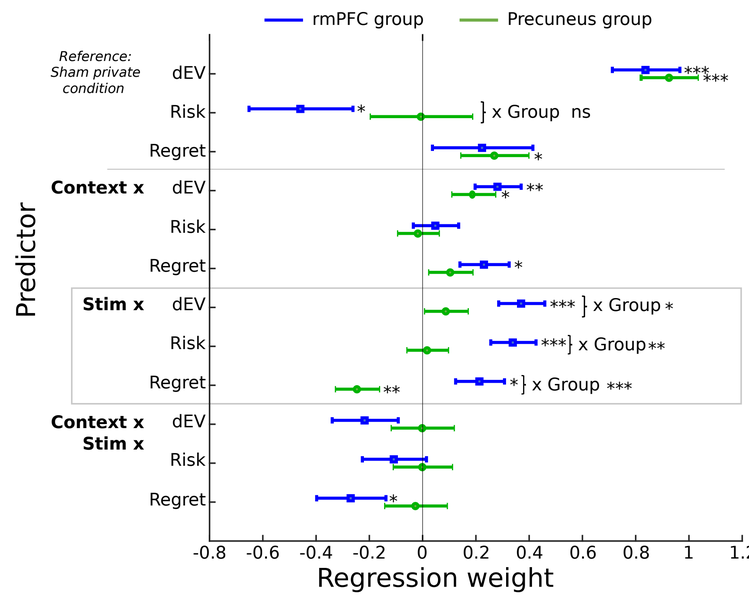
References

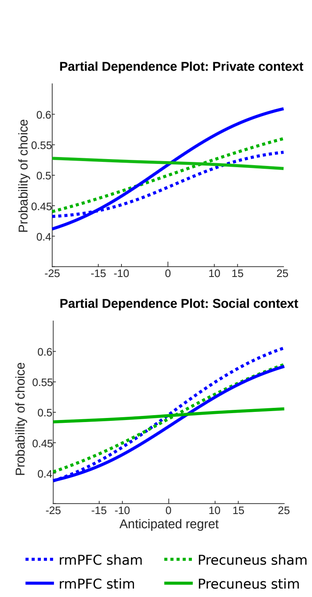
1. Camille N, Coricelli G, Sallet J, Pradat-Diehl P, Duhamel JR, Sirigu A. The involvement of the orbitofrontal cortex in the experience of regret. Science. 2004;304(5674). 2. Bault N, Joffily M, Rustichini A, Coricelli G. Medial prefrontal cortex and striatum mediate the influence of social comparison on the decision process. Proc Natl Acad Sci USA. 2011;108(38). 3. Fouragnan EF, Chau BKH, Folloni D, Kolling N, Verhagen L, Klein-Flügge M, et al. The macaque anterior cingulate cortex translates counterfactual choice value into actual behavioral change. Nat Neurosci. 2019 May;22(5). 4. Dadario NB, Sughrue ME. The functional role of the precuneus. Brain. 2023 Sep 1;146(9). 5. Bault N, di Pellegrino G, Puppi M, Opolczynski G, Monti A, Braghittoni D, et al. Dissociation between Private and Social Counterfactual Value Signals Following Ventromedial Prefrontal Cortex Damage. J Cogn Neurosci. 2019 Jan 11;31(5). 6. Munuera J, Rigotti M, Salzman CD. Shared neural coding for social hierarchy and reward value in primate amygdala. Nat Neurosci. 2018 Mar;21(3). 7. Zeng K, Darmani G, Fomenko A, Xia X, Tran S, Nankoo JF, et al. Induction of Human Motor Cortex Plasticity by Theta Burst Transcranial Ultrasound Stimulation. Annals of Neurology. 2022;91(2).

Results

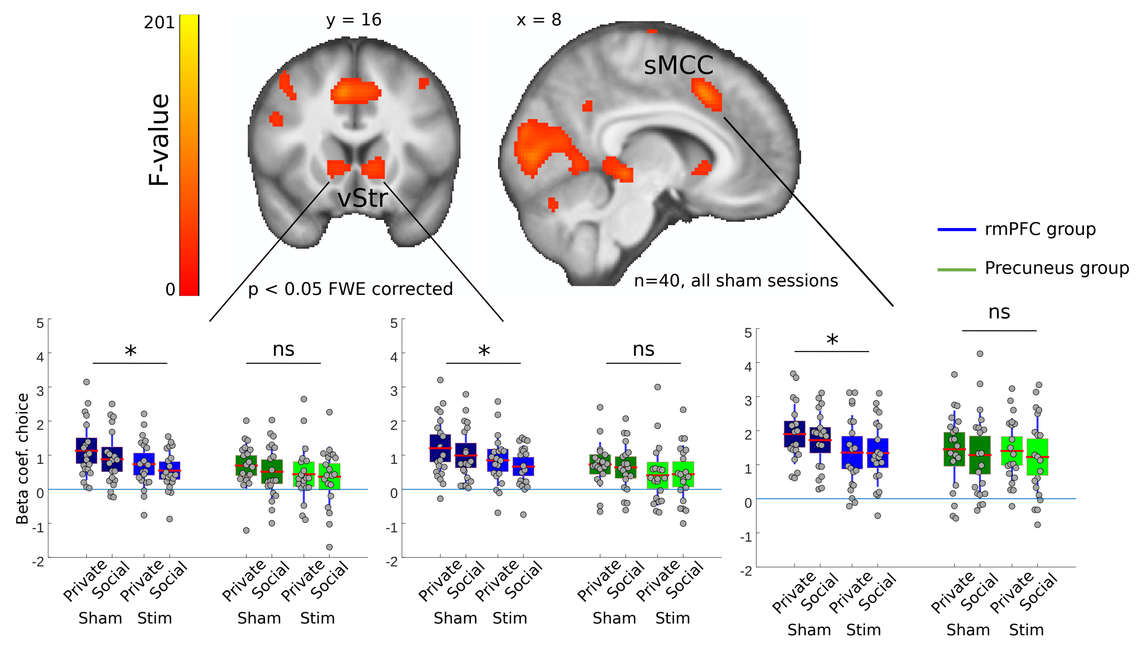
Model of choice

$$\Pr(choice)=\frac{1}{1+\exp(\alpha+\beta.\mathrm{dEV}+\gamma.regret+\delta.risk)}$$



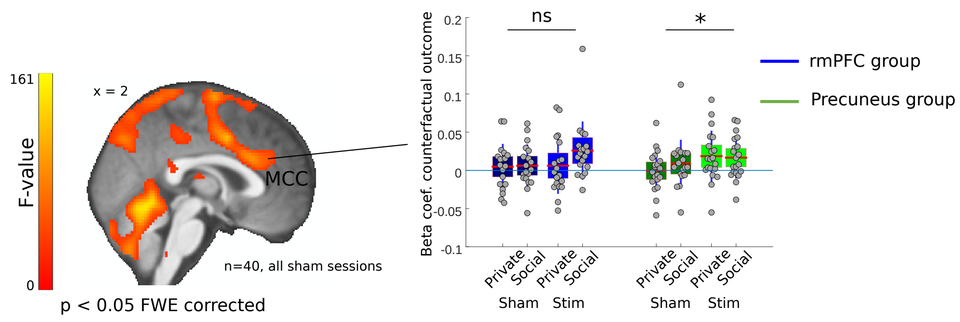


fMRI results - choice phase



At the time of choice, TUS of the rmPFC reduced neural activity in the striatum and midcingulate cortex.

fMRI results - outcome phase



At the time of outcome, TUS of the Precuneus increased neural activity associated with the outcome of the unchosen option in the midcingulate cortex

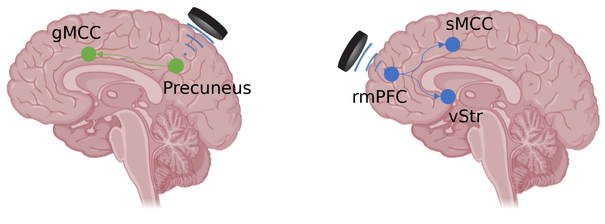
Discussion

After receiving TUS in the rmPFC, participants:
- chose more often the lottery with **highest expected value**
- chose more often the lottery associated with **minimal anticipated regret**
- were **less risk averse**

After receiving TUS in the Precuneus, participants:
- did **not anticipate regret** anymore

TUS effects on behaviour are specific to the stimulation site

The effect of TUS at the neural level are consistent with the known connectivity of the stimulated regions



No specific effect of TUS found on social aspects of the decision process