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Abstract

Flexible switching between self and other perspectives is critical for adaptive social cognition and is thought to rely on the dynamic regulation of self–other representations. Although neuroimaging implicates the dorsomedial prefrontal cortex (dmPFC) and right temporoparietal junction (rTPJ) in perspective-taking, causal evidence for their contributions to perspective switching is lacking. Here, we applied focal transcranial direct current stimulation (f-tDCS) to the dmPFC and rTPJ while participants completed a visual perspective-taking task requiring switches between egocentric and altercentric viewpoints. Anodal stimulation to either site selectively increased the cognitive cost of switching back to the egocentric-perspective, without affecting switches into the altercentric-perspective. Rather than facilitating re-engagement with self-referential processing, stimulation enhanced altercentric persistence or impaired disengagement from the altercentric perspective. These findings provide novel causal evidence that both the dmPFC and rTPJ are involved in regulating the inhibition and updating of self–other representations during perspective switching. Results suggest that stimulation of these hubs may disrupt efficient realignment to the self, highlighting their role in maintaining an altercentric cognitive state. Future studies are required to uncover the precise neural computations that account for the comparable behavioural outcomes observed across distinct social brain hubs.

Keywords: switching; social cognition; social brain; visual perspective taking; non-invasive brain stimulation

The ability to flexibly switch between one's own perspective and that of another is a cornerstone of social cognition, underpinning everyday communication, cooperation, and conflict resolution. Yet despite its importance, the cognitive and neural mechanisms that enable perspective switching remain incompletely understood. Behavioural research shows that representing both viewpoints and shifting between them places heavy demands on executive control, but it is not clear how different brain regions contribute to these processes, or how they interact to resolve conflicts between self and other. Neuroimaging work has repeatedly highlighted the right temporoparietal junction (rTPJ) and dorsomedial prefrontal cortex (dmPFC) as key hubs (Healey & Grossman, 2018; Schurz et al., 2015), but causal evidence is sparse. Brain stimulation studies point to a functional dissociation with rTPJ supporting the adoption of another's perspective, and dmPFC regulating egocentric bias (Martin, Huang, et al., 2019), yet the causal role of these regions in perspective switching is untested. Clarifying these mechanisms is not only a theoretical challenge for cognitive neuroscience, but also carries translational significance: practitioners working with conditions marked by social difficulties (e.g., autism, psychosis, brain injury) could benefit from mechanistic insights into perspective-switching and how it might be strengthened through targeted interventions.

Visual perspective taking refers to the ability to understand what another person can see or how they see it (Kessler & Rutherford, 2010). It is typically measured using spatial tasks that require participants to judge a scene from another person's viewpoint. One common paradigm is the Director Task (Apperly et al., 2010), in which participants follow instructions from a "director" who has a limited view of the objects, requiring them to inhibit their own perspective. This task exemplifies level-one perspective taking, which involves understanding or representing what another person can or cannot see. Perspective-taking ability can be assessed by comparing performance when taking another's perspective versus one's own and has been used to demonstrate an egocentric bias in both communication (Keysar et al., 2000) and social cognition (Martin, Perceval, et al., 2019). Alternatively, the influence of a task-irrelevant perspective can be investigated by comparing performance between congruent and incongruent trials, with incongruent trials slowing responses due to interference (Martin, Perceval, et al., 2019). However, the cost of switching between perspectives provides a further metric, offering insight into the cognitive demands of maintaining and flexibly shifting between perspectives.

Switching between perspectives places substantial demands on cognitive resources. When self and other perspectives diverge, participants exhibit larger congruency effects (slower responses when the two perspectives conflict) and show increased fixations on task-relevant targets, as revealed by eye-tracking (Ferguson et al., 2017). Elevated fixation counts are widely interpreted as an index of heightened cognitive demand, reflecting the need for additional attentional resources to extract and integrate information. This demonstrates a switch-dependent cognitive demand related to perspective selection. Moreover, asymmetrical switching costs have been demonstrated. For example, Samuel et al. (2019)

found a cost of switching when returning to take their own perspective, but not when switching to adopt another person’s point of view. This was taken as evidence that greater inhibition is required to inhibit the egocentric perspective and lifting this inhibition incurs a greater processing cost. Their findings suggest that the egocentric-perspective operates as the cognitive default, necessitating active suppression when taking another’s perspective. Once inhibited, reactivating the egocentric-perspective requires additional executive control, reflected in increased response times and error rates. These results underscore the role of executive processes, particularly inhibition and cognitive control, in managing perspective shifts.

Despite perspective switching being a fundamental process underpinning higher-order social cognition, including theory of mind (ToM; Bradford et al., 2019) and referential communication (Damen et al., 2019), little is known about underlying brain-behaviour associations. The dmPFC is thought to play a key role in managing and integrating social information, including maintaining distinct self–other representations and flexibly selecting between them (Denny et al., 2012; Martin et al., 2017; Wittmann et al., 2016, 2021). In functional imaging studies, activity in this region also increases when tasks require greater cognitive control or a switching of strategy (Clairis & Lopez-Persem, 2023). On the contrary, the rTPJ has been closely linked to the ability to inhibit one's own egocentric perspective and to simulate another’s viewpoint (Martin, Huang, et al., 2019; Payne & Tsakiris, 2017; Soutschek et al., 2016). It is especially active during tasks that require adopting a non-egocentric perspective, including higher-order social cognitive tasks (Schurz et al., 2014). Together, these regions form part of a broader social-cognitive network that enables the dynamic and flexible adoption of different visual perspectives in complex social contexts.

Non-invasive brain stimulation (NIBS) offers a method for moving from correlational to causal evidence in the study of social cognition. One such technique, focal transcranial direct current stimulation (f-tDCS), involves modulating activity in specific brain regions through the application of weak electrical currents to the scalp (Meinzer et al., 2024). Previous research has demonstrated the efficacy of tDCS in influencing social cognitive processes (Sellaro et al., 2016), including visual perspective taking (Martin et al., 2017, 2020, 2021; Martin, Huang, et al., 2019; Martin, Su, et al., 2019; Van Elk et al., 2017; Yao et al., 2021). Across multiple replicated studies, f-tDCS has provided causal evidence for the involvement of the right temporoparietal junction (rTPJ) and the dorsomedial prefrontal cortex (dmPFC) in modulating the integration and distinction of self–other representations (Martin, Huang et al., 2019; Martin, Su, et al., 2019). For instance, Martin, Huang et al. (2019) demonstrated dissociable effects of stimulating these two regions on perspective-taking performance. Specifically, stimulation of the dmPFC enhanced the influence of the altercentric perspective during egocentric judgments across both level-one and level-two perspective-taking tasks. In contrast, stimulation of the rTPJ selectively attenuated the influence of the egocentric perspective during altercentric judgments, particularly in tasks requiring embodied perspective-taking. These findings highlight the distinct yet complementary contributions of the dmPFC and rTPJ in regulating self–other representations. However, direct causal evidence for their involvement in dynamic perspective switching remains unknown.

Therefore, the present study used focal transcranial direct current stimulation (f-tDCS) to identify the causal involvement of two key hubs of the social brain, the dorsomedial prefrontal cortex (dmPFC) and the right temporoparietal junction (rTPJ), in perspective switching. Based on prior evidence for distinct roles of the dmPFC and rTPJ in self–other processing, we predicted potentially dissociable effects of stimulation at each site. Specifically, we expected that dmPFC stimulation would increase the cognitive cost of returning to the egocentric perspective after adopting an altercentric perspective, reflecting enhanced integration or sustained maintenance of other related information that makes disengagement more effortful. In contrast, we predicted that rTPJ stimulation would reduce the cognitive effort required to switch into the altercentric perspective, consistent with improved inhibition of the egocentric viewpoint and more efficient adoption of another's perspective. Together, these predictions were intended to test whether dmPFC and rTPJ make dissociable contributions to the dynamic regulation of self–other representations during perspective switching.Importantly, much of the evidence supporting functional dissociations between dmPFC and rTPJ derives from paradigms examining perspective adoption or interference rather than dynamic switching. It therefore remains unclear whether these regions exert directionally specific effects when participants must rapidly disengage from one perspective and reinstate another. Under switching demands, shared control processes such as updating or disengagement of self-other representations may be engaged across both regions, potentially yielding convergent behavioural outcomes despite distinct computational roles.

Methods

Participants

Fifty-two healthy young adults were recruited from [redacted for anonymous review]. All participants were tDCS naive, free from neurological or psychiatric conditions, and reported no substance abuse. All participants provided written consent in accordance with the Declaration of Helsinki (1991: p1194) and completed a safety screening form and brief interview to ensure they were safe to participate. Participants also completed the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) and the Autism Quotient (AQ; Baron-Cohen et al., 2001). These measures were used to ensure groups receiving rTPJ or dmPFC stimulation were comparable. All participants were provided with a small monetary compensation or course credits for their time. The Ethics committee of [redacted for anonymous review] approved the study.

Power Analysis. A power analysis was conducted for the 2 × 2 × 2 × 2 × 2 mixed ANOVA ($\alpha = .05$, $1 - \beta = .80$), assuming sphericity ($\varepsilon = 1$) and a within-subject correlation of $\rho \approx .50$. With 52 participants (26 per brain region group), the design was sensitive to detect small-to-medium within-subject effects (minimum detectable $d_p \approx 0.39$) and medium-to-large between-group effects (Cohen's $d \approx 0.78$; $f \approx 0.39$; $\eta_p^2 \approx .13$). Sensitivity for representative interactions fell within the small-to-medium range ($f \approx 0.20$–0.25).

Study Design, Randomization, and Allocation

The study employed a sham-controlled, double-blind, cross-over design. Healthy young adults completed two experimental sessions in which they received either active or sham stimulation, with stimulation site (dmPFC or rTPJ) serving as the between-subjects factor. All participants first completed baseline screening and questionnaires prior to stimulation.

Randomization of stimulation site (dmPFC vs. rTPJ) was performed using a computer-generated randomization list prepared by an investigator who was not otherwise involved in data collection. Stimulation order (active vs. sham) was counterbalanced within each group, such that half of the participants received active stimulation in the first session and half received sham stimulation first. A minimum interval of three days was required between sessions to avoid carry-over effects.

Double-blinding was maintained using the "study mode" of the DC-Stimulator, which requires entry of a stimulation code. Codes were generated and assigned by a researcher independent of recruitment and testing, thereby ensuring that neither participants nor experimenters were aware of stimulation condition during data collection.

Transcranial Direct Current Stimulation (tDCS)

Stimulation was administered using a one-channel direct current stimulator (DC-Stimulator Plus®, NeuroConn) with two concentric rubber electrodes (Bortoletto, Rodella, Salvador, Miranda, & Miniussi, 2016; Gbadeyan, Steinhauser, McMahon, & Meinzer, 2016; Perceval et al., 2017). Compared with conventional tDCS montages that typically employ large sponge electrodes (for example ~25–35 cm^2) and produce relatively diffuse electric fields, concentric ring configurations yield a more spatially restricted distribution of current density. Finite element modelling demonstrates that ring montages concentrate peak electric field magnitude beneath the centre electrode and substantially reduce peripheral spread relative to rectangular pads, resulting in greater spatial focality at the cortical target (Datta et al., 2009). Quantitative modelling work further shows that concentric configurations can confine the induced field to a smaller cortical region while maintaining comparable field strength at the target site, supporting their use for focal neuromodulation (Edwards et al., 2013). The rubber electrodes therefore allow more focal stimulation while maintaining compatibility with a standard one channel stimulator. The centre electrode was 2.5cm in diameter and the return electrode was 7.5/9.8 cm for both the dmPFC and rTPJ sites. Electrodes were attached using an adhesive conductive gel (Weaver Ten20® conductive paste) and held firmly in place using an elastic EEG cap placed over the head in a conventional manner whilst covering the electrodes and preventing any electrode movement. The conductive gel was applied in a consistent manner, covering the electrodes with a thickness no more than 1mm. This ensured the electrodes remained in position and prevented the rubber from contacting the skin directly. The gel was prevented from spreading by ensuring the hair was parted such that the gel would contact skin directly and not require excessive pressure. Both dmPFC and rTPJ sites were identified using the 10-20 International EEG system. The dmPFC was located by finding 15% of the distance from the Fz towards the Fpz. The rTPJ was located by finding CP6. For both the sham and anodal stimulation conditions, the current was ramped up to 1 mA over 5 s and then ramped down over 5 s. In the anodal stimulation condition the current reached 1 mA and was maintained at this intensity for 20 min before ramping down. In the sham condition, stimulation was delivered for a total of ~50 s (5 s ramp up, 40 s at 1 mA, 5 s ramp down), after which the device remained on without current for the remainder of the 20 min session to preserve blinding.

Current modelling was conducted using SimNIBS version 4.1 (Thielscher et al., 2015; see Figure 2). Simulation parameters were selected to closely replicate the experimental setup, including the intended positions of the central anode and surrounding ring cathode, electrode dimensions, current intensity, and gel thickness. Electrode and gel thickness were set to 2 mm and 1 mm, respectively, and standard tissue conductivity values provided within SimNIBS were applied.

For the dmPFC montage, the centre of the anode was defined in MNI space by first identifying the Fz and Fpz positions and calculating the distance between them. The target scalp location was then determined as 15% of this distance from Fz towards Fpz, corresponding to MNI coordinates [0.5, 71.7, 46.1].

For the rTPJ montage, the centre of the anode was positioned at CP6, based on the international 10–10 EEG system as implemented in SimNIBS. In both montages, ring cathodes were arranged concentrically and equidistantly around the central anode.

Figure 1 illustrates the normal component of the E-field for anodal focal tDCS targeting both the rTPJ and dmPFC. Peak electric field strength reached 0.13 V/m for the rTPJ montage and 0.09 V/m for the dmPFC montage.

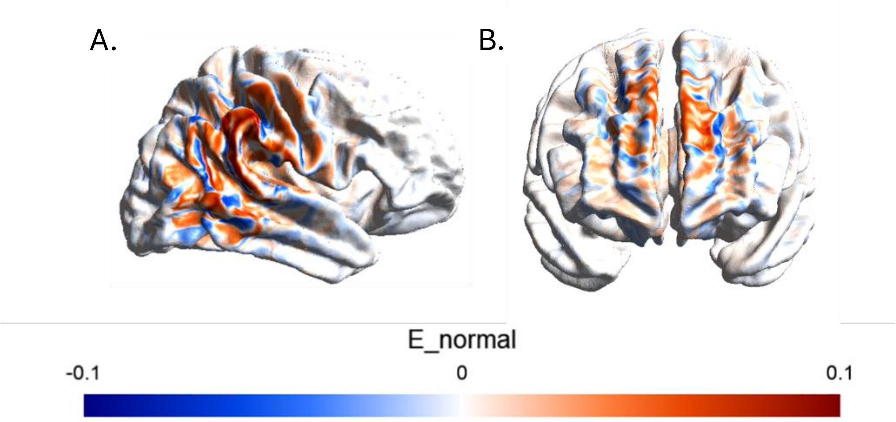

Figure 1. Surface rendering of the distribution and intensity of the estimated electric field for the two target sites with anodal stimulation. **A** Right temporoparietal junction, **B** Dorsomedial prefrontal cortex. We present the normal component.

Mood was assessed using the Visual Analogue Mood Scale (VAMS; Folstein & Luria, 1973), administered before and after each stimulation session. The VAMS evaluates current emotional states on 0–10 visual analogue scales across eight dimensions: afraid, confused, sad, angry, energetic, tired, happy, and tense. Higher scores reflect greater intensity of the given mood. To quantify change, post-stimulation ratings were subtracted from pre-stimulation ratings. Individual items were further grouped into composite indices: positive mood (energetic, happiness) and negative mood (fear, confusion, sadness, anger, fatigue, tense). Composite change scores were included in the analyses.

Adverse effects were assessed after each session using the self-report questionnaire developed by Brunoni et al. (2011). Participants rated the intensity (recoded to: 0 = absent, 1 = mild, 2 = moderate, 3 = severe) and occurrence of common side effects, including headache, neck pain, scalp pain, tingling, itching, burning sensations, skin redness, sleepiness, concentration difficulties, and sudden mood changes. Total scores are presented for analysis.

Finally, to evaluate blinding efficacy, participants were asked at the end of the second session: *“Do you think the active stimulation was delivered in the first session or the second session?”* Participants were forced to select an option even if they were unsure.

Visual Perspective Taking Task

A detailed description of the Visual Perspective Taking (VPT) Task used in the present study can be found in Martin, Perceval, et al. (2019). Briefly, participants were presented with a street scene containing one to four tennis balls, which appeared randomly across six possible locations. Rubbish bins were strategically placed to render the balls either visible or occluded from the hypothetical gaze of a humanoid avatar, who was positioned at one of three locations along the street. Participants were instructed to consider any tennis balls positioned behind the avatar as not visible from the avatar's perspective. In a non-agent control block, a traffic light replaced the avatar, and participants were instructed to judge whether the light would directly hit the tennis balls, serving as a non-social analogue of the visual perspective judgment.

Participants were asked to report either how many tennis balls they themselves could see (egocentric perspective) or how many were visible to the avatar, or would be directly hit by the light (altercentric perspective). On half of the trials, the number of visible tennis balls was identical from both egocentric and altercentric viewpoints (congruent trials), while in the other half, the number differed (incongruent trials). The prompt (you or other) remained on the screen for 750ms followed by a fixation cross for 500ms, then the street scene. The scene remained on the screen until the participant made a response (see Figure 2 for a schematic of the VPT task).

The crucial adaptation in Martin, Perceval et al. (2019) was that the task was balanced for perspective switching demands. On half of the trials, participants were required to maintain the same perspective as on the previous trial (stick trials), whereas on the other half they were required to switch between egocentric and altercentric perspectives (switch trials). All conditions were fully balanced across the task. The task consisted of four blocks of 88 trials each. The avatar and traffic light blocks were presented separately and completed either in the first two or the final two blocks. Block order was counterbalanced across participants, such that half of the cohort completed the avatar condition first and the other half completed the traffic light condition first. Participants were able to take rest breaks between each block. Participants were informed about the requirements of the new block and presented with ten practice trials for both avatar and light conditions. Counterbalancing block order ensured that any potential practice or fatigue effects were distributed across conditions rather than systematically associated with a particular agent or perspective condition.

The experiment was conducted on desktop computers in dedicated tDCS laboratories at [redacted for anonymous review]. Stimuli were presented, and responses recorded, using *PsychoPy* (v2023.2). Participants responded via a standard keyboard, with stickers placed over the number keys 1, 2, 9, and 0, corresponding to 1, 2, 3, and 4 tennis balls, respectively. The spacebar was used to indicate 0 tennis balls. Both response latency (in ms) and response accuracy (correct/incorrect) were recorded for each trial. The primary outcome measure was reaction time (RT) for correct responses; accuracy was considered only to exclude incorrect trials from the RT analysis and exclude participants who did not complete the task correctly.

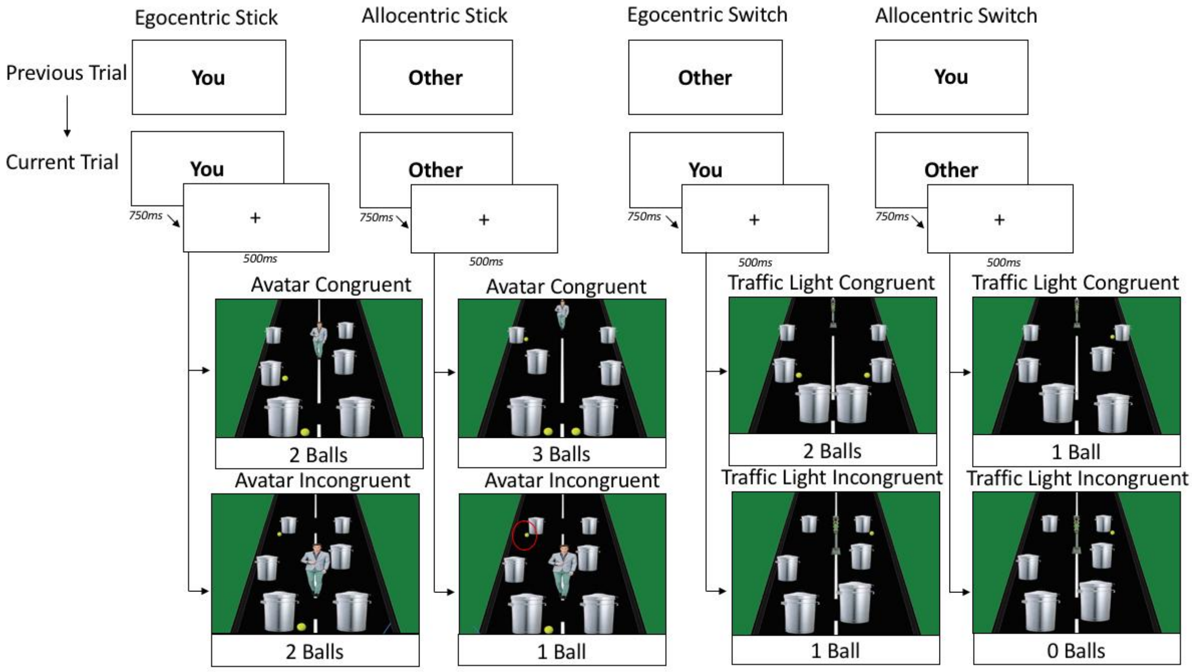

Figure 2. The VPT task (with correct responses for the level one perspective taking task). In the level one perspective taking condition, participants were asked “how many tennis balls can you/other see/light directly shines on?”. If the trial was preceded by the same perspective this was considered a stick trial, whereas if participants were required to change perspectives, this was classified as a switch trial. Only the congruency of the current trial was evaluated in the current study.

Statistical Analysis

Response times for correct responses were analysed. Individual responses were removed if they were greater than three standard deviations from the individual’s mean. Participants were excluded from the specific VPT task if they scored 50% correct or less on any condition within the task. This resulted in the removal of 2 participants at the dmPFC stimulation site and 3 at the rTPJ site. All were replaced to achieve the desired sample size. The task was designed to incur minimal response errors. Accuracy was high across all conditions and groups and was therefore not analysed in the present study. Following outlier and inaccurate trial removal, the number of trials per condition remained high across all conditions (see Supplementary Table S1). On average, each cell contained approximately 18–21 trials per participant (M range = 17.62–21.46).

All analyses were conducted using JASP version 0.18.3. A 2×2×2×2×2 mixed-design ANOVA was performed with the following within-subjects factors: stimulation (sham vs. anodal), agent (avatar vs. light), congruency (congruent vs. incongruent), and switch (stick vs. switch). Brain region (dmPFC vs. rTPJ) was included as a between-subjects factor. The dependent variable was response time (ms). We present the cognitive effects and stimulation effects separately for ease of interpretation.

Mood change was analysed using two separate 2x2 mixed-design ANOVAS for both negative and positive mood change. The between-subject factor was stimulation site (rTPJ v dmPFC) with stimulation type (sham v anodal) the within-subject factor. Likewise, we conducted a 2x2 mixed design ANOVA for total adverse effects with the same factors.

Exploratory Analyses

Exploratory analyses examined whether AQ and HADS scores moderated stimulation effects (see Supplementary 3 for full details).

Results

The stimulation groups (rTPJ v dmPFC) did not differ significantly on age or any baseline mental health measures (see Supplementary section 1).

Cognitive Effects

Independent of stimulation, several robust cognitive effects emerged. A main effect of perspective was observed, $F(1, 50) = 160.81$, $p < .001$, $\eta^2_p = .763$, with egocentric-perspective trials (M = 972.68 ms) yielding faster responses than altercentric-perspective trials (M = 1041.49 ms). A strong main effect of congruency was also present, $F(1, 50) = 264.24$, $p < .001$, $\eta^2_p = .841$; responses were faster on congruent trials (M = 937.13 ms) than incongruent trials (M = 1077.04 ms). Likewise, there was a significant main effect of switching, $F(1, 50) = 106.20$, $p < .001$, $\eta^2_p = .680$, with stick trials (M = 979.01 ms) faster than switch trials (M = 1040.02 ms).

The perspective × congruency interaction was also significant, $F(1, 50) = 6.64$, $p = .013$, $\eta^2_p = .117$. The congruency effect was more pronounced under altercentric-perspective trials (congruent: M = 973.12 ms; incongruent: M = 1109.86 ms) than under egocentric-perspective trials (congruent: M = 901.14 ms; incongruent: M = 1042.30 ms; see Figure 3). Finally, a strong congruency × switch interaction was observed, $F(1, 50) = 119.87$, $p < .001$, $\eta^2_p = .706$, with the congruency effect amplified in switch trials (congruent: M = 936.53 ms; incongruent: M = 1147.47 ms) compared to stick trials (congruent: M = 906.59 ms; incongruent: M = 1031.12 ms; see Figure 4).

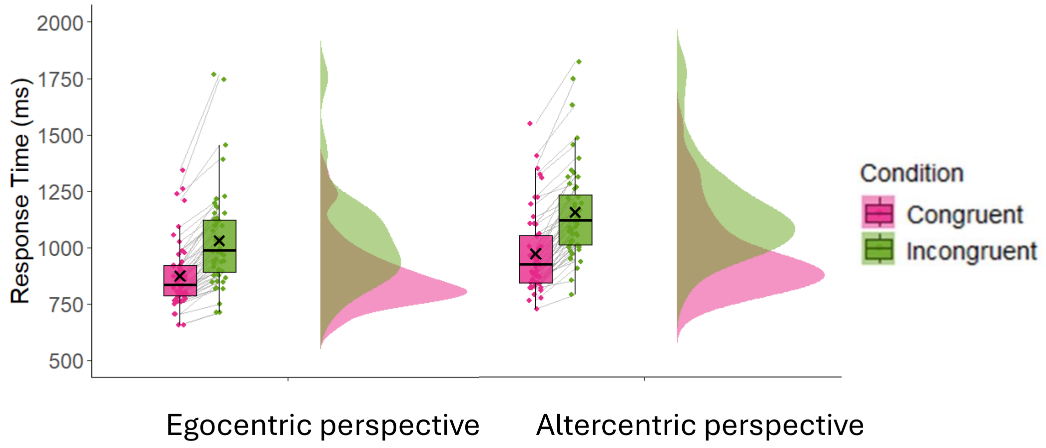

Figure 3. Response times for congruent and incongruent trials during egocentric and altercentric perspective taking.

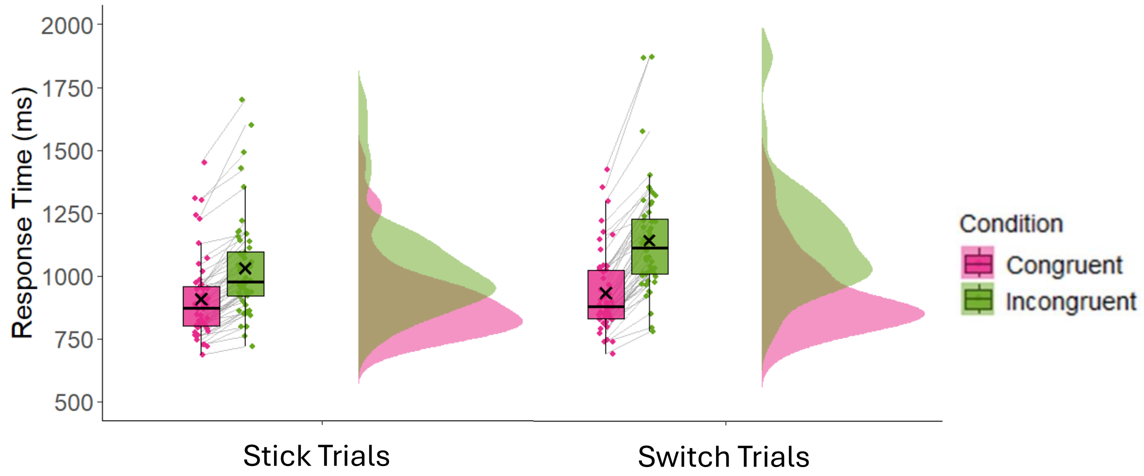

Figure 4. Response times for congruent and incongruent trials during stick or switch trials.

The social nature of the altercentric perspective (avatar v traffic light) did not influence congruency scores. However, the agent × perspective × switch interaction was significant, *F*(1, 50) = 16.94, *p* < .001, η^2_p = 0.25, indicating that the social nature of the altercentric perspective influenced general switching costs. Separate 2x2 RM-ANOVAs were computed for avatar and traffic light conditions. During the avatar condition, the switch x perspective interaction was not significant, F(1,51)=1.21, p=.28, η^2_p = 0.02. However, during the traffic light condition, the switch x perspective interaction was significant, F(1,51)=15.91, p<.001, η^2_p = 0.24. Post-hoc t-tests (Holm corrected), indicated a significant difference between stick and switch trials during egocentric perspective taking, t(51)=6.45, p<.001, d=0.35, but a larger effect during altercentric perspective taking, t(51)=10.87, p<.001, d=0.58 (see Figure 5).

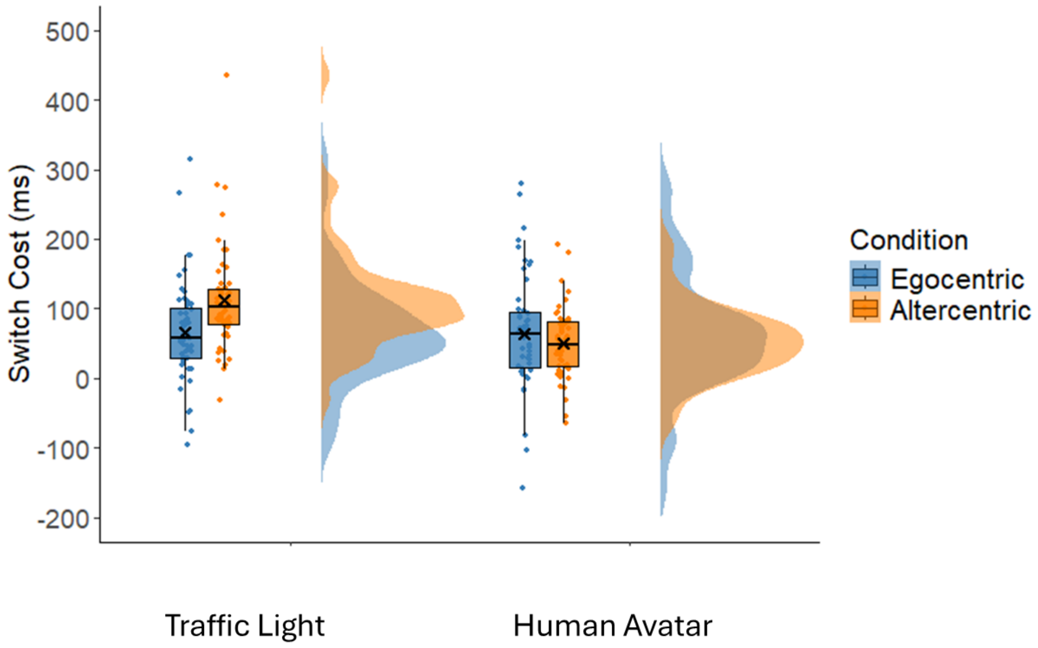

Figure 5. Switch costs when transitioning to or from the egocentric and altercentric perspective for both non-social traffic light and social human avatar conditions

Stimulation Effects

A significant three-way interaction was identified between stimulation × perspective × switch, *F*(1, 50) = 5.10, *p* = .028, η^2_p = 0.09. However, this did not differ by region, stimulation x perspective x switch x region, *F*(1,50) = 0.45, *p* = .45, η^2_p = 0.01. To provide strength of evidence in favour of a null effect for region specific effects, we conducted a Bayesian analysis. A Bayesian model comparison tested whether the stimulation × perspective × switch effect differed by region. The model including the four-way interaction was compared with an otherwise matched model excluding that interaction. The resulting Bayes factor was BF10 = 0.291 (BF01 = 3.432), indicating moderate evidence for the reduced model (null interaction with region).

To explore the stimulation × perspective × switch interaction, separate repeated-measures ANOVAs were conducted for egocentric and altercentric perspective trials. For egocentric-perspective trials, a significant stimulation × switch interaction was observed, *F*(1, 51) = 4.89, *p* = .03, η^2_p = .09 (see Figure 6.). Post hoc comparisons (Holm-corrected) revealed that during sham stimulation, switch trials (M = 964.41 ms, SE = 30.90) were significantly slower than stick trials (M = 911.21 ms, SE = 28.73), t(51)= 4.89, *p* <.001, *d* = 0.24, but this difference was greater during anodal stimulation, (switch trials: M = 1005.49, SE = 33.29; stick trials: M = 928.63, SE = 28.92), t(51)= 7.09, *p* <.001, *d* = 0.35. Thus, stimulation selectively increased the cost of switching when participants returned to the egocentric perspective.

In contrast, for altercentric-perspective trials, the stimulation × switch interaction was not significant, $F(1, 51) = 0.15$, $p = .70$, $\eta^2_p = .003$.

All other higher-order interactions involving stimulation were non-significant (*ps* > .13). Full statistical output is provided in supplementary table 1.

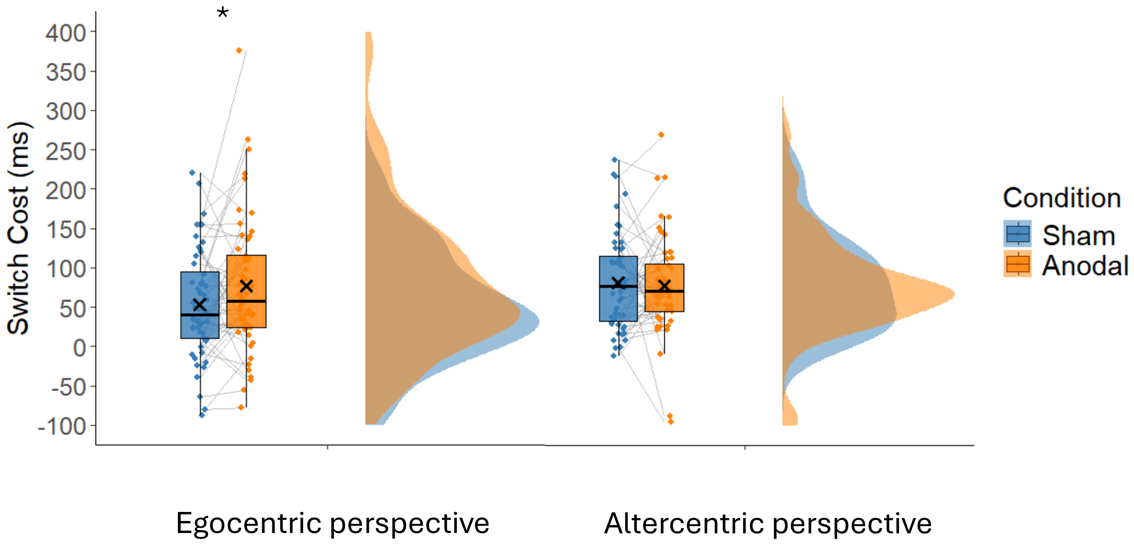

Figure 6. Stimulation to either the dmPFC or the rTPJ increased the cost of switching back to the egocentric perspective.

Mood change, adverse effects, and blinding

There were no stimulation related effects on mood change, adverse effects. Blinding was achieved at both regions. See supplementary section 2 for detailed statistics.

Exploratory Analyses of Trait Moderation

Exploratory analyses examined whether individual differences in Autism Spectrum Quotient (AQ) and Hospital Anxiety and Depression Scale (HADS) scores moderated the effects of stimulation. AQ significantly interacted with stimulation, such that higher AQ scores were associated with greater slowing under anodal relative to sham stimulation. In contrast, higher anxiety scores were associated with reduced slowing under anodal stimulation. These effects did not interact with task variables (e.g., perspective or switch), and no significant effects were observed for depression scores (see Supplementary Materials for full details).

Discussion

The present study investigated the causal role of the right temporoparietal junction (rTPJ) and dorsomedial prefrontal cortex (dmPFC) in switching between egocentric and altercentric perspectives using focal anodal transcranial direct current stimulation (f-tDCS). Contrary to our hypothesis, stimulation to either the rTPJ or dmPFC selectively slowed response times when participants switched from the altercentric to the egocentric perspective, with no corresponding effect when switching in the opposite direction. Although prior HD tDCS studies report dissociable effects of dmPFC and rTPJ stimulation during perspective taking, these paradigms have primarily examined interference during sustained perspectives or the initial adoption of another viewpoint. In contrast, the present task isolates the temporal dynamics of disengaging and reinstating perspectives. As such, the absence of a regional dissociation was not expected, but is theoretically meaningful, and may reflect the recruitment of a shared updating mechanism during switching.

Perspective-taking requires participants to evaluate visual scenes either from their own point of view or that of another agent. Switching between these perspectives entails managing competing representations and inhibiting one perspective in favour of another. The TPJ and dmPFC have been consistently implicated in visual perspective taking across neuroimaging and brain stimulation studies (Healey & Grossman, 2018; Martin et al., 2019; Martin et al., 2019; Martin et al., 2017, 2020, 2021; Santiesteban et al., 2012; Schurz et al., 2015; Wittmann et al., 2021), yet their causal contributions to perspective switching have remained unclear.

Our findings suggest that stimulation to either region disrupts the re-engagement of the egocentric perspective after adopting another's viewpoint. One account is that anodal tDCS enhanced altercentric processing or increased the salience of the other's perspective, making it more difficult to disengage when required to return to the egocentric frame. This interpretation is consistent with evidence linking the rTPJ and dmPFC to attentional reorientation, perspective integration, and conflict monitoring (Corbetta et al., 2008; Gläscher et al., 2012; Martin et al., 2019; Oehrn et al., 2014; Yao et al., 2021). Rather than supporting perspective taking in isolation, these regions appear to contribute to resolving competition between self and other representations, particularly when transitioning between them. This interpretation is also consistent with accounts proposing that these regions contribute to the prioritisation and maintenance of socially relevant representations.

From a mechanistic standpoint, stimulation of the TPJ may have enhanced processes related to perspective co-representation (Krall et al., 2015; Martin et al., 2019; Martin et al., 2021; Santiesteban et al., 2012), increasing interference from the altercentric perspective when participants attempted to reinstate their own viewpoint. Similarly, dmPFC stimulation may have amplified processes related to self–other integration or the maintenance of competing representations. Although a conflict monitoring account is plausible, the absence of a congruency-specific effect makes this explanation less likely. Instead, the data are more consistent with a bias toward maintaining the altercentric representation for longer, leading to increased costs when switching back to the egocentric perspective. This suggests that both regions contribute to sustaining socially relevant representations, even when they are no longer task-relevant.

These findings contrast with studies reporting facilitation of perspective taking following TPJ stimulation (e.g., Santiesteban et al., 2012), although such studies typically focus on the initial adoption of another's perspective rather than switching dynamics. The present results suggest that while rTPJ and dmPFC may support adopting another's viewpoint, their overactivation can hinder disengagement from that viewpoint. This highlights that neuromodulatory effects on social cognition are likely context-dependent and sensitive to the direction of control, such as switching into versus away from another's perspective.

Importantly, stimulation did not affect switching into the altercentric perspective, indicating an asymmetry in how these regions support perspective transitions. Shifting away from the egocentric perspective is typically more demanding (Martin et al., 2019), requiring suppression of a dominant self-referential frame. By enhancing activity in regions associated with self–other processing, anodal tDCS may promote stronger engagement with the altercentric perspective, which in turn increases the cost of disengaging from it. This pattern supports the view that these regions are involved not only in adopting another's perspective but also in maintaining and regulating competing representational frames.

In addition to stimulation effects, several cognitive effects were observed. Greater congruency effects during both switch trials and altercentric trials indicate that conflict between self and other perspectives is amplified when task demands are highest, consistent with previous work (Ferguson et al., 2017). Switch trials require reconfiguration of the current perspective, increasing competition between representations, while altercentric trials require suppression of a dominant egocentric frame. Together, these findings highlight the role of representational conflict and inhibitory control in visual perspective taking and show that such conflict is modulated by both perspective type and switching demands.

Importantly, the traffic light condition cannot be considered a genuine perspective in the same sense as a human avatar. Instead, it functions as a nonsocial rule-based condition in which participants follow an arbitrary mapping. The significant switch by perspective interaction observed in this condition was not predicted, but is theoretically informative. It likely reflects the additional demands of alternating between qualitatively different task rules, rather than perspective-taking per se, consistent with a geometric or rule-based account.

Critically, however, the absence of a corresponding interaction in the avatar condition provides important insight into the nature of social perspective taking. If switching between self and other perspectives relied on the same type of task-set reconfiguration as in the non-social condition, comparable switching costs would be expected. Instead, the lack of modulation suggests that egocentric and altercentric perspectives are processed within a shared representational framework when anchored to a social agent. This reduces the need for explicit rule switching and results in lower switching costs. Such a shared representational format for self and other perspectives has been proposed in both behavioural and neurocognitive accounts of social cognition (Decety & Jackson, 2004; Sebanz et al., 2003).

Thus, the asymmetry between conditions does not reflect stronger perspective effects in the social condition, but rather, inflated switching costs in the non-social condition. This pattern suggests that human avatars provide a natural representational anchor, allowing self and other perspectives to be treated as functionally equivalent. In contrast, non-social rules require additional task-set reconfiguration, leading to increased switching demands. These findings therefore speak directly to debates about the social nature of visual perspective taking (Conway et al., 2017; Santiesteban et al., 2014), indicating that efficiency in switching depends not only on rule complexity but also on whether the task is grounded in a social context.

Critically, the present findings have important implications for models of dmPFC and rTPJ specialization. These models typically emphasise functional dissociations, with the rTPJ linked to attentional reorienting and perspective computation, and the dmPFC associated with self–other integration and higher-order social inference. However, the observation of similar behavioural effects following stimulation to both regions suggests that such specialization may be context-dependent. While dissociable contributions may emerge during sustained or static perspective taking, the dynamic demands of switching between perspectives may recruit a more integrated process. Under these conditions, distinct neural computations may converge on a shared functional outcome, namely the updating of representational priority between self and other perspectives. This results in non-dissociable behavioural effects despite differences in underlying neural mechanisms.

Despite the comparable behavioural effects, this does not imply functional equivalence between the dmPFC and rTPJ. It remains possible that each region contributes distinct computations that converge on a common behavioural outcome during switching. The dmPFC may bias integrative or monitoring processes, whereas the rTPJ may influence attentional reorienting or representational weighting. Under switching demands, these distinct perturbations may lead to similar delays in reinstating the egocentric perspective. Future cognitive work able to disentangle such processes would be valuable. Moreover, future work combining brain stimulation with neuroimaging methods such as fMRI or EEG will be important for determining whether similar behavioural effects arise from shared network-level changes or from distinct regional dynamics. Connectivity analyses, network modelling, and dual-site stimulation approaches may further clarify how these regions interact within a distributed system.

An additional consideration is that individual differences in social-cognitive traits may modulate responsiveness to neuromodulation. In the present study, exploratory analyses indicated that higher Autism Spectrum Quotient (AQ) scores were associated with a greater behavioural effect of stimulation, whereas higher anxiety scores showed the opposite pattern. Although these effects did not interact with the critical task variables, they suggest that trait-level variability may influence the extent to which stimulation biases self–other processing. This interpretation is consistent with emerging evidence that individual differences in autism-relevant traits can shape the behavioural impact of non-invasive brain stimulation, particularly for stimulation of the temporoparietal junction and related social-cognitive networks (Donaldson et al., 2018). While these findings should be interpreted cautiously given their exploratory nature, they highlight the importance of considering individual differences when evaluating the causal role of dmPFC and rTPJ in social cognition.

The results should also be interpreted in light of several limitations. The sample was predominantly female and drawn from a Western, tertiary-educated population, both of which may influence cognitive processing and responsiveness to stimulation (Martin et al., 2019; Wu & Keysar, 2007). Future studies should examine more diverse samples and consider individual differences in perspective switching and its neural basis. In addition, the present study focused on level one perspective taking. Further work is needed to determine whether similar effects are observed during more embodied forms of perspective taking, such as level two tasks (Martin et al., 2020).

In summary, this study provides evidence that both rTPJ and dmPFC play a causal role in perspective switching, particularly in the disengagement from altercentric representations. The asymmetric slowing observed when switching back to the egocentric perspective suggests that these regions contribute to maintaining socially relevant representations, even when they are no longer required. More broadly, the findings indicate that perspective switching relies on a shared control process that operates across regions typically considered functionally distinct, refining current models of the social brain and highlighting the importance of task dynamics in revealing or constraining functional specialization.

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Conflict of Interest

The authors declare no conflict of interests.

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Data Availability

Data is available on request.

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