The relationship between self-control in intertemporal choices and the control of egocentric during perspective taking

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Abstract

We infer the thoughts and feelings of other people by taking their perspectives, the accuracy of which depends on abilities to control egocentric bias. Similar processes could arguably be used to understand how we would be affected by future events, such as delayed rewards in intertemporal decisions, by allowing us to accurately take the perspective of future selves. In this paper, we test this idea in two studies. In Study 1, we attempted to lower preferences for delayed rewards to examine if this redced abilities to control egocentric bias in a visual perspective-taking task. In Study 2, we examined the neural overlap in intertemporal decision-making and the control of egocentric bias in a false-belief theory-of-mind task. In both studies, a positive relationship was identified between behavioural and neural markers of egocentric bias control and preferences for delayed rewards. The overall pattern of results suggest the overlap in processes of egocentric bias control and those that determine preferences in intertemporal choices, and demonstrate for the first time the effect of sexual arousal on social cognition in reducing abilities to separate one's own perspective from others'.

Keywords: intertemporal choice, temporal discounting, egocentric bias, perspective-taking, temporoparietal junction

Introduction

The ability to see the world from different perspectives, imagining the thoughts or feelings that might occur in us and others in a variety of situations, is highly useful. It helps to take the perspectives of others to understand and interact effectively with them. This ability is also useful in an intertemporal context, for instance, when faced with decisions or events with delayed consequences, we typically shift our own perspective into the future to assess how these might impact us later. The relationship between these capacities for taking the perspectives of others and future selves has previously been speculated (see Jamison & Wegener, 2010; Mitchell et al., 2011; Buckner & Carroll, 2007), but it is still unclear if and how they overlap. To investigate this, we previously laid out an empirically-grounded framework to make plausible hypotheses of how these capacities relate to each other (O'Connell et al., 2015), called the Simulation-based Model of Intertemporal Preferences (SMIP).

The SMIP uses the phenomenon of temporal discounting to illustrate how perspective-taking abilities might underlie the perception of future events. Temporal discounting describes how when making choices between rewards to be received now or larger rewards later, the delayed larger reward decreases in subjective value when its receipt is delayed further in the future, leading to smaller but immediate rewards being preferred, and the rate of which is indexed by the steepness of the "discounting curve".

One way the accuracy of perspective-taking can become compromised is through the false presumption that other people think or feel the same way as we do, an error called egocentric bias, as measured using false-belief theory-of-mind (ToM) tasks. Neuroimaging studies of psychiatric patients and children have found that better control of egocentric bias during ToM judgments corresponds to stronger coinciding neural activity in the right temporoparietal junction (rTPJ) (Gweon et al, 2012; Kana et al., 2009; Dodell-Feder et al, 2013). Further reports indicate the rTPJ is preferentially activated for false beliefs that require egocentric bias control, and not true beliefs (Hartwright et al., 2012; Sommer et al., 2007), specifying the role of this region in egocentric bias control, and not general capacities of perspective-taking.

The SMIP hypothesizes that intertemporal choices situations are analogous to social situations in which perspective-taking occurs, in how there is a target perspective to be inferred, and an egocentric perspective which needs to be controlled for. The SMIP argues that from one's current egocentric perspective, delayed rewards have to be waited for to be received, and therefore incur costs-of-waiting that diminishes their subjective value. In contrast, from the perspective of one's future self, there is no cost of waiting because they are at the right point in time to receive the reward instantly. Controlling this egocentric bias when taking the perspective of the future self should therefore lead to delayed rewards being preferred more, leading to less steep temporal discounting. The SMIP further explicitly predicts the rTPJ as one of the key nodes for control of egocentric bias during both perspective-taking and intertemporal choices. Note these are only a few of the mechanisms and predictions outlined in the SMIP which are relevant to the current study (for further information see O'Connell et al., 2015).

A recent paper from Soutschek et al. (2016) provides direct support for this neural overlap hypothesized by the SMIP. In two studies, repetitive transcranial magnetic stimulation (TMS) was administered to participants' rTPJ regions to disrupt its function. It was found that both the degree of egocentric bias exhibited by participants in a visual perspective-taking task, and preferences for immediate over delayed reward choices in a temporal discounting task, were both subsequently increased. Furthermore, a positive relationship between egocentric bias and immediate reward preferences was observed across individuals. By demonstrating a relationship between egocentric bias and increased temporal discounting, these two findings can be explained by the SMIP framework.

In this paper, we tested the hypotheses of the SMIP by examining the relationship between egocentric bias control and temporal discounting in two studies: 1) examining the effect on one process when the other is experimentally manipulated, 2) examining their neural overlap using fMRI.

Study 1: Sexual Arousal Manipulation

In Study 1, instead of brain stimulation as per Soutschek et al. (2016), we attempted to increase the steepness of temporal discounting psychologically by inducing sexual arousal with erotic images, which multiple reports indicate is reliable means of increasing the steepness of temporal discounting (Kim & Zauberman, 2013; Van den Bergh, Dewitte, & Warlop, 2008; Wilson & Daly, 2004). Sexual arousal is thought to lead to steeper temporal discounting by causing a generalized state of desire, in which the immediacy of a reward overshadows its objective value. For a comparison control, equally arousing sports images were used, as per Kim & Sauberman (2013). The Director task was used to index control of egocentric bias.

Methods

Participants and procedure

Heterosexual German speaking males were recruited (n = 90, range 19-59 years, mean 29.3) performed tasks in the following order: 1) temporal discounting (baseline), 2) visual perspective-taking Director task, 3) temporal discounting (manipulation-check), 4) Continuous performance task (CPT). After task 1) the impulsivity manipulation was initiated, where in separate groups participants viewed either erotic or arousal-matched sports images for 8 s, which occurred every trial of the Director task, 6 trials of the temporal discounting task, 13 trials of the CPT, for an average of one image every 14 s.

Temporal discounting (baseline)

Participants made intertemporal choices between a variable amount of money now (< 100€) or 100€ at one of four randomly selected delays (months: 1, 3, 6, 12). The amount of immediate options and indifferences-points were calculated using the double-limits algorithm, and temporal discounting rates (k) were estimated by fitting a hyperbolic non-linear model to each participant's indifference-points

Director task

In the Director task, participants move objects around a set of shelves as instructed by a "director" standing on the opposite side, but to take into account that some objects cannot be seen by the director because they are occluded from their side of the shelf. This requires the participant to control for egocentric information from their own viewpoint when inferring the director's. The Director task was computerized with a real person in the role of director, and the impression of actual shelves was created by positioning the participant's screen back-to-back with the director's. A previously used eye-gaze metric of egocentric bias was used - the average dwell time (sum of 100 ms fixations) to distractor objects, a basic index of how much the distractor object (the correct object from the participant's egocentric viewpoint) was considered as the correct option.

Participants' heads were placed in a chin-rest positioned in front of an Eye-tribe 30 Hz eye-tracker. Trials began with a fixation cross when the experimenter read aloud a scripted instruction, then pressed a key to present the shelves on screen. Instructions in experimental trials referred to distractor objects on dimensions of spatial (e.g. "move the top ball" could refer to a higher hidden ball), size (e.g. "move the large ball" could refer to a larger hidden ball), or semantic (e.g. "move the mouse" could refer to a computer mouse or a hidden toy mouse). In control trials instructions referred to objects without competing referent. 30 trials were performed (24 experimental, 6 control), featuring 9 sets of 6 objects, presented in a fixed randomized order.

Temporal discounting task (manipulation-check)

Participants performed intertemporal choices a second time to check the sexual arousal manipulation. Immediate reward options were present from ranges (±10€) around participants' baseline indifference points in 32 trials. Changes in temporal discounting were estimated as value-weighted changes from baseline temporal discounting.

Continuous Performance Task (CPT)

The CPT measures general attention to test possibility that erotic images affected egocentric bias by merely distracting attention from task goals. Single digit numbers were presented for 100 ms (1 s ISI), and participants had to press one key following a sequence of 3-7 (average every 10 of 130 trials), and another key otherwise.

Results

Effects of sexual arousal manipulation

Note tests of the hypothesis were directional and conducted at the 1-tailed level. In the Director task, dwell time to the distractor object was significantly higher following erotic (M = 317 ms, SE = .18) images versus sports images (M = 270 ms, SE = .17), $t(88) = 1.9$, $p = .032$, d = .4 (Figure 1B), an effect not observed in control trials, $t(88) = .043$, $p = .97$. Although changes from baseline temporal discounting were ordinally higher following erotic (M = 1.5, SE = 3.3) compared to sports (M = -.6, SE = 3.6) images, this difference was not significant, $t(88) = .44$, $p = .33$. There was no significant difference in error rates in the CPT task between the erotic (M = 5%, SE = .02) or sports (M = 2%, SE = .01) image groups, $t(88) = 1.3$, $p = .18$.

Relationship between egocentric bias and temporal discounting

A linear regression was used to model the relationship between baseline temporal discounting rates and egocentric bias, controlling for the influence of group. The model found that after controlling for the group factor ($B = -.524$, $t = -2.11$, $p = .038$), temporal discounting was a significant positive predictor of egocentric bias ($B = .316$, $t = 2$, $p = .048$). Note, data from the second temporal discounting task could not be used for this form of analysis because in this task, choice options were pre-determined from baseline, and not the double-limits algorithm which is required to reliably estimate new temporal discounting rates (Figure 1A).

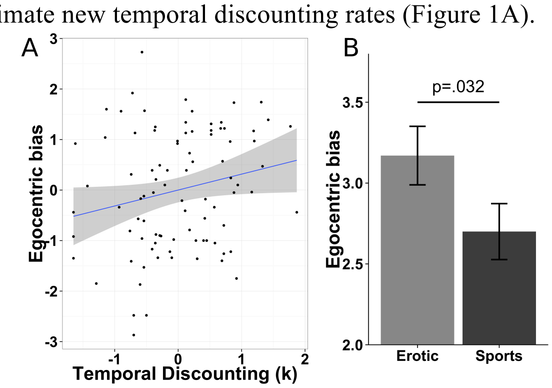

Figure 1. A: Scatterplot of temporal discounting and egocentric bias (residuals partialling out group effects). **B:** Group differences in egocentric bias (error-bars: SE).

Discussion

In support of the hypothesis, it was found that people who exhibited steeper temporal discounting were also more susceptible to egocentric bias. Also in line with this view, egocentric bias was higher following erotic stimuli, which although previously reported to lead to steeper temporal discounting, was not specifically observed here.

Contrary to previous findings, sexual arousal from did not significantly alter temporal discounting here, limiting the extent to which changes in egocentric bias can be attributed to changes in self-control. One explanation for this null finding is that the arousing effects of erotic images had habituated by the second time the temporal discounting task, after already 15 mins of repeated exposure to images. It's worth noting that in pilot data, where temporal discounting was the first task performed, steeper temporal discounting was found following erotic images compared to sports images (n = 32, $p = .05$), giving some confidence that full counterbalancing of tasks in this study would have increased chances of observing effects of sexual arousal on temporal discounting. However, this null effect still warrants caution in interpreting the results.

Study 2: fMRI

In Study 2, we tested the relationship between egocentric bias and temporal discounting using fMRI. If rTPJ activity during perspective-taking is a correlate of egocentric bias control, as hypothesized by the SMIP and suggested by empirical evidence, then people higher in this marker should prefer delayed rewards more during intertemporal choices. To test this hypothesis, we used a false-belief functional localizer task to extract activity in the rTPJ related to egocentric bias control from each participant. We further tested if activity in this rTPJ cluster was higher when delayed rewards are chosen, as would be expected if egocentric bias control reduces temporal discounting.

Methods

Participants and procedure

36 English speaking adults (21 female, aged 18-34 years, mean 22.6) performed the following tasks in order: outside scanner, 1) temporal discounting task; inside scanner, 2) temporal discounting task, 3) ToM localizer task.

Temporal discounting (outside scanner)

Same as temporal discounting task (baseline) in Study 1, except with pounds in place of euros, and using the following delays (months: 1, 3, 6, 9, 12, 18).

Temporal discounting (in scanner)

In the scanner, participants were presented with intertemporal choices featuring three delays (months: 6, 9, 12). As in the temporal discounting task (manipulation-check) in Study 1, immediate options were estimated from participants' temporal discounting data collected outside scanner in order to predict how participants would decide and efficiently balance the number of trials in conditions of immediate (IMM) and delayed (DEL) choices, this time from value ranges ±£5-15 indifference-points. Trials continued until 32 (balanced across delays) were collected in which each immediate and delayed rewards were chosen (the IMM and DEL conditions). Options were presented together for 5 s, followed by a jittered ITI of 7-15 s.

fMRI temporal discounting acquisition and analysis

25 out of the 36 participants performed the scanner version of the temporal discounting task. Scanning was conducted using a Siemens 3T Trio MRI scanner with an EPI sequence of TR 3 s, TE 30 ms, 2 mm^3 voxel size, and 35 interleaved 3 mm slices. Data were preprocessed using a GLM in SPM8, with slice-timing correction, realignment for motion correction, field map unwarping, and sequential co-registration. We contrasted rTPJ activity in DEL > IMM separately for each individual in their specific rTPJ ROIs from the ToM task, by first registering individual rTPJ ROIs to MNI space using FEAT, and the mean contrast values of DEL and IMM conditions were then extracted.

False-belief ToM localizer task

The false-belief localizer task consisted of 10 stories about other people's beliefs (False Belief) or historical facts (FACT). Each trial started with a blank screen for 12 s, followed by the story for 10 s, and then a question screen for 4 s, which required a "True" or "False" response.

fMRI ToM localizer data acquisition and analysis

Scanning was conducted with an EPI sequence of TR 2 s, TE 30 ms, 2 mm^3 voxels, and 37 interleaved 3 mm slices. Using FSL, data were field map unwarped, pre-whitened, motion corrected, slice-time corrected, and high-pass filtered at 128 Hz and smoothed at 8 mm FWHM in native space. False Belief and FACT trials were defined as the 14 s of the story and question screens. Using FEAT, clusters from the False Belief > FACT contrast were identified at height threshold z = 2.3, cluster threshold p < .05, minimum size 200 voxels, Gaussian Random Field FWER corrected.

rTPJ ToM localization procedure

An iterative threshold-adjusting procedure was adapted from Mitchell (2008) to identify individual rTPJ clusters related to false-belief processing. This procedure involved increasing the height activation threshold of the False Belief > FACT contrast in native space in steps of 10-1, starting from p < 0.01 until a cluster in the rTPJ region was identified 25-50 voxels in size. Percentage signal change in participants' individual clusters, hereafter referred to as $rTPJ_{FB}$. For thoroughness of reporting, this procedure was applied to other regions associated with ToM in the left temporoparietal junction (lTPJ) and precuneus.

Results

Data cleaning and sample selection

rTPJ clusters could not be localized for two participants, and 2 participants were extreme outliers in the DEL vs. IMM in the rTPJ ROI (Tukey's interquartile range), This threshold identified two cases for exclusion.

Correlation between egocentric bias control rTPJ response and temporal discounting

A significant negative correlation was found between temporal discounting rates k and $rTPJ_{FB}$, r = -.32, p = .03 (Figure 2) ($lTPJ_{FB}$, r = -.36, p = .02; $precuneus_{FB}$, r = -.37, p = .01), an effect still significant in the temporal discounting scanning session subsample, r = -.36, p = .04.

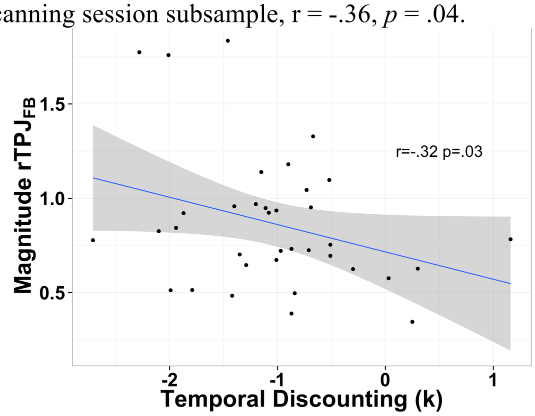

Figure 2. Scatterplot of temporal discounting and magnitude of $rTPJ_{FB}$ activity.

fMRI temporal discounting results

A significant difference was found in individual rTPJ ROIs in DEL > IMM, t = 2.06, p = 0.025 (Figure 3B).

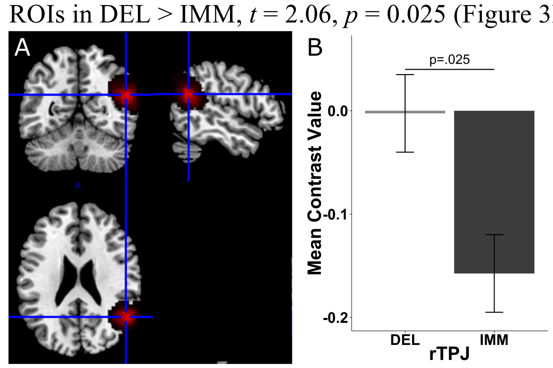

Figure 3. A: Overlaid individual rTPJ ROI clusters (crosshairs at peak). B: Differences between choice conditions in individual rTPJ ROIs (error bars: SE).

Discussion

In Study 2, we found two pieces of evidence in support of the hypothesis that better control of egocentric bias reduces steepness of temporal discounting. First, people exhibiting a higher rTPJ response during false-belief judgments, a putative neural marker of egocentric bias control, had less steep temporal discounting. Second, responding in the same rTPJ cluster involved in egocentric bias control was higher when delayed rewards were preferred over immediate rewards when making intertemporal choices in the scanner.

Evidently, this interpretation of the results relies on a reverse-inference about the rTPJ's function of egocentric bias control. Neural markers of egocentric bias control have the advantage of being continuous, and more resistant to ceiling effects that standard measures (e.g. false-belief tasks) are often prone to, making them better suited for measuring variability in healthy adults. Increased rTPJ activity has been repeatedly shown to be associated with higher ToM accuracy (Gweon et al., 2012; Kana et al., 2009). Similarly here, despite ceiling effects in accuracy in the current ToM data, a trending positive correlation was noted between this accuracy and magnitude of rTPJ activity ($r=.23$, $p=.09$), providing some behavioural support for the function of rTPJ activity claimed here. Some studies with children, who do not show the ceiling effects typically seen in ToM tasks in adults, have shown positive links between accuracy and preferences for delayed rewards (Launay et al., 2015; Marchetti et al., 2014).

The exact function of the rTPJ in perspective-taking remains an open question. Based on reports of the rTPJ's importance in focusing attention on distinctions between self and others (e.g. in terms of preferences; Nicolle et al., 2012), it has been proposed that this region helps avoid the perceptual blurring of self and other perspectives that drives egocentric bias (Brass et al., 2009). More generally, the rTPJ has been claimed to be involved in orienting attention towards task goals (Corbetta & Shulman, 2002). In any form of choice, it could be argued that a goal to maximize reward outcomes, irrespective of the time of receipt, becomes activated. In intertemporal choices, delayed rewards are larger, and hence, most relevant to this goal. In contrast, immediate rewards could be considered distractions that draw attention away from this goal, shifting focus instead to the immediacy of enjoyment. This view of rTPJ function would account for its observed increased activation when choosing delayed rewards.

General Discussion

The effects in this paper are modest and mixed, but support the view that temporal discounting is related to abilities of perspective-taking, as hypothesized by the SMIP. To sum up, in both Study 1 and Study 2, individual differences in perspective-taking corresponded to steepness of temporal discounting. In Study 1, an experimental manipulation previously shown to led to steeper temporal discounting was found to increase egocentric bias. However, because of the null effect on temporal discounting itself, the extent to which this egocentric bias can be attributed to processes overlapping with temporal discounting is limited. In Study 2, evidence for the SMIP was found in how individually-localized neural markers of egocentric bias control were higher when delayed rewards were preferred over immediate ones. In all, these findings, provide exploratory first steps in examining potential connections between intrapersonal and interpersonal forms of cognition.

Such a connections has numerous theoretical and practical upshots. Linking the fields of social cognition and intertemproal decision-making would allow the benefits of one (e.g. conceptual frameworks in social cognition, mathematical models in decision-making) be transferred to the other. Practically, it would suggest the potential of temporal discounting as a continuous and fast index of perspective-taking abilities in adults, which are currently required in social cognition research.

To-date, the overwhelming amount of research in intertemporal decision-making has restricted focus to the concept of value, and inputs and outputs to its computation. Increasingly, more concepts about how this value is psychologically represented have come under study, including future prospection (Kwan et al., 2015), and feelings of connectedness with one's future (Urminsky, 2017). The SMIP aims to extend this line of inquiry by attempting to provide a mechanism for how these representations are built, and why they degrade to cause temporal discounting, parsimoniously based on mechanisms that already underlie social abilities.

Sexuality is an integral social setting, but its impact on perspective-taking abilities has not been tested before now. The present finding thus furthers understanding of how an everyday social context modulates mentalizing capacities, which vital information for theories to build sufficiently detailed descriptions of these processes (for similar work, (Galinsky, Magee, Ena Inesi, & Gruenfeld, 2006; Kanske, Böckler, Trautwein, Parianen Lesemann, & Singer, 2016; Todd, Forstmann, Burgmer, Brooks, & Galinsky, 2015).

The current findings, along with those of Soutschek et al. (2016), encourage further investigations of the overlap in intertemporal choice and perspective-taking, but the noted inconsistencies warn that conclusive evidence could be challenging to find. One clear example of this is the difficulty in detecting overlap in capacities that are measured by tasks with vastly different structures and demands. The results also flag sexual contexts as influential to the ability to look past our own perspective to better understand those of others, calling for further investigations into this important but little understood topic. Future work can test the generalizability of these effects in larger samples, using different measures, especially ones that can measure these capacities in more closely matched structures.

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