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Projecting my envy onto you: Neurocognitive mechanisms of an offline emotional egocentricity bias

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ABSTRACT

Humans often project their own beliefs, desires and emotions onto others, indicating an inherent egocentrism. In five studies we investigated the neurocognitive mechanisms underlying emotional egocentricity bias (EEB) and specifically an offline EEB, defined as the projection of one's own tendency to react with a certain emotional response pattern in a given situation onto other people. We used a competitive reaction time game associated with monetary gains and losses that allowed inducing feelings of envy and Schadenfreude. While we found evidence for the first hand experience of envy and Schadenfreude, we also observed an offline bias, that is participants on average projected feelings of envy and Schadenfreude when having to judge others. Importantly the extent of experienced and projected social emotions were highly correlated. This bias was observed when participants were both directly involved and also as an uninvolved party, suggesting the offline bias to be independent of the presently experienced emotion. Under increased time pressure however an online bias emerged whereby participants just projected their presently experienced emotions onto the other. Finally, we show that on the neural level shared neuronal networks underlie the offline EEB at least for envy. Thus, for envy, activity of the same part of anterior insula was sensitive to individual differences both in the experience and the projection of envy. These findings outline the set of circumstances leading to specific types of empathic attribution biases and show that individual differences in the experience of social emotions are predictive of the offline egocentricity bias both on a behavioral as well as a neural level. These data extend present models on the neurocognitive mechanisms of interpersonal understanding in the socio-affective domain.

Introduction

How humans come to understand others poses a perennial quandary to scientists studying this ability. Recent advances in unraveling how one can make predictions of others' mental and emotional states have shown that typically, humans rely on their own experiences to make inferences on what others might think or feel (Gallese and Goldman, 1998; Keysers and Gazzola, 2007; Lamm et al., 2011; Mitchell, 2009; Singer et al., 2004). The set of one's own experiences used to infer the states of others can range from currently experienced physical states (Van Boven and Loewenstein, 2003) to personality traits (Krueger and Clement, 1994; Krueger and Zeiger, 1993) and attitudes (Biernat et al., 1997). Thus, humans are remarkably prone to assuming that others are like them (Gilovich et al., 1983). This assumption is useful when the experience of self and other are matched, but more often than not, it will lead to a bias in judging others egocentrically when they differ. Affective egocentricity bears hidden costs in that it can lead to interpersonal (Thompson and Loewenstein, 1992) as well as group conflict (Chambers et al., 2006). Understanding and isolating the underlying causes of such a socially detrimental proclivity is thus critical in helping to reduce potentially resulting conflict and antisocial behavior.

There is a large body of evidence in the domain of behavioral psychology on the occurrence of egocentric biases in the context of cognitive social judgments (for reviews see Karniol, 2003; Robbins and Krueger, 2005), particularly when targets are assumed to be similar to oneself (Ames, 2004). However, while covering mostly personality traits and attitudes, emotional states as a source of egocentric judgments have been largely ignored (but see O'Brien and Ellsworth, 2012 for studies on the projection of visceral states onto others; Van Boven and Loewenstein, 2003). Further, the neural mechanisms of why such egocentric biases occur are almost missing entirely. So far previous studies have rather focussed on uncovering brain regions associated with overcoming egocentricity rather than what gives rise to this egocentricity in the first place. Thus, recently it was shown that adjusting from the tendency to project one's own preferences onto others recruits brain regions known to be involved in mentalizing, such as medial prefrontal cortex (Tamir and Mitchell, 2010). Further, a recent neuroimaging study on emotional egocentricity bias (EEB) showed using pleasant and unpleasant tactile stimulation that adults' judgments of others' emotional states were strongly influenced by the affective stimulation they were simultaneously

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experiencing (Silani et al., 2013) and that the recruitment of right supramarginal gyrus (rSMG) was critical in overcoming this. More recently this EEB was shown to be increased in children compared to adults in the context of a paradigm inducing positive and negative emotions by means of monetary rewards and punishments (The Egocentricity Monetary Reward and Punishment Paradigm, in short EMOP; Steinbeis et al., in press). Children judged others to feel more positive when they themselves had just won and judged others to feel negative when they themselves had just lost, which was coupled with reduced recruitment of rSMG. Thus, in two studies, rSMG was shown to be a crucially related to overcoming an EEB that arises out of one's current emotional state (Silani et al., 2013; Steinbeis et al., in press). However, what remains unclear is how such emotional egocentricity occurs in the first place and what the neural mechanisms are that give rise to this.

To study this we used a paradigm capable of inducing higher level social emotions arising out of social comparisons with others, such as envy and Schadenfreude. Thus, there is by now an extensive body of literature on the occurrence of social comparison in adults and the influence that the welfare of others has on one's own well-being (Festinger, 1954; Gibbons and Buunk, 1999). Research has shown that processes of social comparison can lead to feelings of envy and Schadenfreude. Envy can be defined as feeling bad about someone's superiority particularly in something that is personally highly relevant. Schadenfreude in turn entails pleasure at another's suffering or doing worse than oneself (Smith and Kim, 2007; Smith et al., 1996). We were interested in whether those participants who experience more envy or Schadenfreude themselves in social comparison situations also attribute more envy and Schadenfreude onto others when engaging in empathic judgments and seeing others in situations likely to elicit such emotions. Note, that even though we use a paradigm that elicits social emotions to test this, such affective projections are not limited to social emotions only. Thus, it is possible to conceive of the tendency to project basic emotional states such as anger or sadness onto others to the same extent as one experiences these states in comparable situations. Therefore, even though we are using a specific test case of social emotions to test for this hypothesis, we assume that such mechanisms apply to any emotional state that can be projected.

This novel paradigm uses a speeded reaction time game with monetary rewards and punishments to induce positive and negative emotions in participants and an agent who is playing the same game with the participants (the EMOP). Participants simultaneously play a competitive game where in each round both can either win or lose depending on their performance. Full feedback of both player's wins and losses is displayed to both participants and depending on the condition, of interest is either the effect of the other's wins and losses on judging one's own emotional experience or the effect of one's own wins and losses on judging the other's emotional experience. The EMOP has been shown to induce positive and negative feelings in both players and crucially to infer the presence of social emotions such as envy and Schadenfreude in participants (Steinbeis and Singer, 2013; Steinbeis et al., in press). Thus, in the context of this task envy is defined as feeling worse when losing while the competitor wins compared to both participants losing; this is measured as the difference in rating between the condition where participants lose and the competitor wins compared to the condition when both lose. Schadenfreude on the other hand is defined as feeling better when winning while the competitor lost compared to both participants winning; this is measured as the difference in rating between the condition where participants win and the competitor loses compared to the condition when both win.

Importantly, this paradigm was designed to give the possibility to assess the existence of two types of EEB (see Fig. 1). The first type of EEB is indicated by participants having just won or lost money during the game and simply projecting their present pleasant or unpleasant feelings onto the other when having to judge how another feels that just won or lost money during the very same game. Because this type of EEB results from the direct projection of one's current online affective experience we refer to it as an online EEB. Thus in the context of our task a negative bias is said to occur when others are rated as feeling less positive after winning when participants themselves had lost compared to won. A positive bias in turn is said to occur when others are rated as feeling less negative after losing when participants themselves had won compared to lost (see Fig. 1). In contrast, another type of EEB is indicated by participants simulating the extent of their own tendency to feel an emotion when making inferences about another's affective reactions in a comparable situation (Fig. 1). Thus, unlike for the online EEB, for this EEB to arise it is not necessary to currently experience the emotion, but rather to simulate one's own emotional state offline if one were in the situation of the target to be judged. Because this EEB is assumed to arise out of a process of a context-dependent internal and offline simulation and not a simple projection of the actual experienced

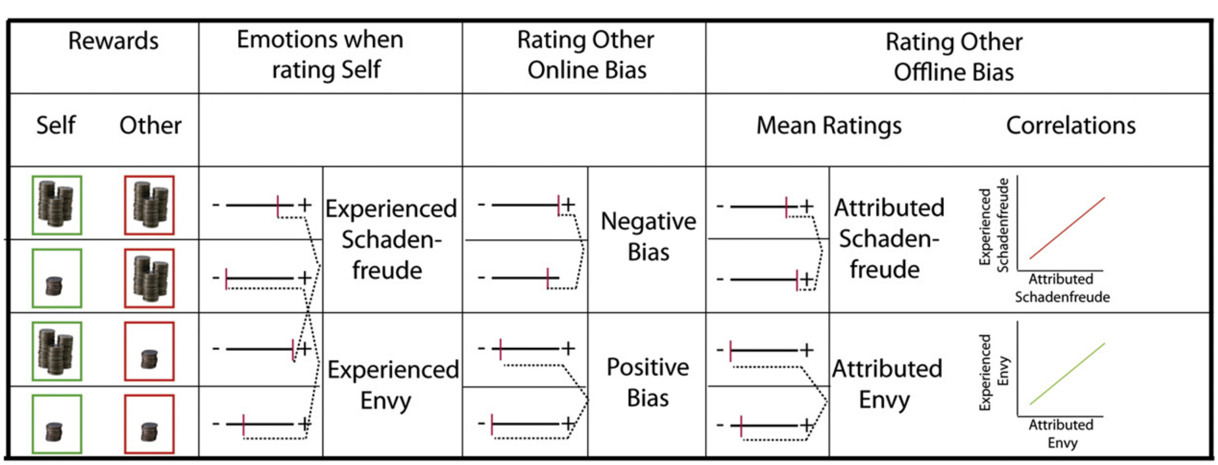

Fig. 1. Operationalization of experienced envy and Schadenfreude as well as the online and offline EEBs. Experienced envy is operationalized as rating oneself to feel worse when seeing the other win while losing oneself compared to both losing; experienced Schadenfreude is operationalized as rating oneself to feel better when seeing the other lose while winning oneself compared to both winning; an online EEB is operationalized as rating the other to feel worse after seeing them win while losing compared to also winning (negative bias) or conversely rating the other to feel better after seeing them lose while winning compared to also losing (positive bias); an offline EEB is operationalized as rating the other to feel better when winning while losing oneself compared to also winning (attributed Schadenfreude) or conversely as rating the other to feel worse when losing while winning oneself compared to also losing (attributed envy). An offline EEB is properly indicated by a correlation between the extent of an emotional experience and the extent of its attribution to others. Note that our representation of wins and losses here is strictly for illustration, since wins were operationalized as the gain of 4 MUs and losses as the loss of 4 MUs.

affective state onto another, we will refer to this as an offline EEB. Thus in the context of our task, the attribution of envy occurs when others (i.e. the competitor) are rated as feeling more negative after participants had won and the competitor lost compared to when both had lost (i.e. attributed envy). Equally, the attribution of Schadenfreude occurs when others are rated as feeling more positive after participants had lost and the competitor won compared to when both had won (attributed Schadenfreude). Crucially, this EEB requires also a correlation between individual differences in experiencing envy and Schadenfreude and individual differences in attributing such tendencies to others (Fig. 1). Importantly, this EEB refers to the projection of the offline simulation of an emotional state and not necessarily to the projection of one's trait (i.e. trait envy or Schadenfreude). While these two may very well be linked, the present investigation focusses solely on projecting simulated emotional states and not traits. The correlation between experienced and attributed emotion is important also in as far as one may assume that participants may have lay theories about others' social emotions in competitive contexts, which may not be linked to the extent that they experience these emotions themselves. Thus, it is only through a correlation between experienced and attributed emotion that an offline bias is fully indicated. The difference between Fig. 1 also illustrates what online and offline EEB should show on average means of opposite directions. This distinction is important for it highlights the myriad ways in which socio-affective judgments can be subject to biases. Thus, for instance online biases may be successfully overcome in that one's present affective experience is discounted, but this could still lead to an offline bias in that one projects one's own general tendency to feel an emotion. Whereas it has been shown that an online EEB can be elicited by means of this paradigm (Steinbeis et al., in press), we were interested if on top of an online EEB it is also possible to elicit an EEB that results from the offline simulation of one's own emotional state if one were in the situation of the target to be judged. Thus, the first major goal of this study was to give first-time evidence for the existence for such an offline EEB (Studies 1a and 1b).

A further goal was to assess the role of contextual factors such as timing and direct emotional involvement influencing when online and offline EEBs are likely to emerge. Previous studies have shown that prolonged periods of time may help in reaching more accurate empathic judgments (van der Heiden et al., 2013) and that egocentric biases increase under time pressure (Epley et al., 2004; Silani et al., 2013), suggesting time to be a crucial factor in the occurrence of egocentric biases. Given that an offline EEB requires first to overcome the tendency to make an online EEB and that to overcome the online bias one's present emotional state has to be discounted, which presumably requires effort and thus a certain amount of time (Silani et al., 2013) we hypothesized that an online bias is more likely to occur than an offline bias when having to make empathic judgments under increased time pressure (Study 2). Further, the online bias requires direct emotional involvement because it is the currently experienced affect that has to be overcome to reach an accurate empathic judgment. For the offline bias we hypothesize that such first-hand experience of a social emotion is not required given that it is assumed to result from active processes of internally simulating what another person is likely to feel in a similar situation based on the emotional tendency one usually displays in a comparable social comparison situation. Thus, the offline bias should also occur even without any direct emotional involvement of the person who is doing empathic judgments, that is when one is not currently experiencing a particular affective state. We therefore hypothesize that the offline bias should also occur in conditions when one merely has to rate the affective experience of another without being directly emotionally implicated in the task itself but being just a neutral passive observer of two other people engaging in this task (Study 3).

One third major goal of this study was to uncover the neural mechanisms underlying the occurrence of the offline EEB (Study 4). In the affective domain, a shared representation account has been proposed for the experience and the understanding of others' primary emotions across several domains (e.g. affective touch, pain and reward; Bernhardt and Singer, 2012; Jabbi et al., 2008; Keysers et al., 2004; Lamm et al., 2011; Mobbs et al., 2009; Singer, 2012; Singer et al., 2004; Wicker et al., 2003). According to this "shared network" hypothesis, the same brain regions are recruited when having a first-hand experience of an emotion or just vicariously observing another person experiencing these emotions. Despite abundant evidence for shared networks in social neuroscience underlying the first-hand and vicarious affective experience of primary emotions and sensations such as touch, disgust, taste and pain, so far these studies have not tested, whether individual differences in the degree to which these emotions are experienced first-hand are predictive of individual differences in the degree to which one attributes such experiences and emotions to others. Shared networks hypotheses however should predict such a correlation based on individual differences in affective experience, whereby the same brain regions underlying the experience of social emotions such as envy and Schadenfreude should also be recruited when attributing these states to others.

Imaging studies suggest that feelings of envy are linked with activation in the dorsal anterior cingulate cortex (Takahashi et al., 2009) and feelings of Schadenfreude with activation in the ventral striatum (Bault et al., 2011; Dvash et al., 2010; Singer et al., 2006; Takahashi et al., 2009), as well as the medial prefrontal cortex (Bault et al., 2011). In addition and as a result of the heightened emotional engagement of our task we expected to see involvement of brain regions involved in processing highly arousing negative emotions, such as the anterior insula, for the experience of envy, a region argued to play a crucial role in aversive social emotions (for a review see Lamm and Singer, 2010). Thus, we would expect differential shared networks underlying the first-hand and vicarious experience of positively valenced social emotions of Schadenfreude and negatively valence emotions of envy. Crucially, however, if shared neural representations of social emotions are related to the offline EEB we would expect the degree of neural activity observed during the first-hand experience of social emotions to be predictive of the extent of this activity observed in the same areas during the attribution of these very social emotions onto the other playing agent. Importantly, because rSMG has been previously been reported to play a crucial role in overcoming the EEB and given that we are currently interested in what gives rise to an EEB in the first place as opposed to the neural mechanisms that help to overcome it, we did not expect any involvement of rSMG in the context of our task. Further, given the affective nature of our task, we specifically predicted the involvement of brain regions involved in processing the affect of oneself as well as others, such as the anterior insula, as opposed to brain regions typically implicated in cognitive perspective taking, such as cortical midline structures (Amodio and Frith, 2006).

To test our hypotheses, we conducted five studies, four behavioral and one imaging study. In the first two studies (Studies 1a and 1b), we established the effectiveness of our EMOP in eliciting social emotions of envy and Schadenfreude in adults as well as an offline EEB. In a third study (Study 2), we show that when increasing the time pressure, we elicit an online EEB, while in a fourth study (Study 3), we show that the offline EEB also occurs when participants were merely passively watching and thus not emotionally engaged in the task at all. A final study (Study 4) using functional magnetic resonance imaging (fMRI) was performed to gain an understanding of the neural mechanisms underlying the offline EEB.

Materials and methods

All studies were approved by the ethics committees of Zuerich University and of the Canton of Zurich (E68/2008) as well as of the University of Leipzig (E029-11-24012011) and all participants gave informed consent to participate in the studies. With the exception of Study 1a, in which subjects were Swiss, all subjects in the remaining studies were German.

Study 1a (establishing the EEB)

Participants

Twenty adults participated in the experiment (10 men; mean age = 21.95 ± 2.34 ± SD years; age range: 19–26.4 years).

Procedure

Testing took approximately 1 hour and participants were invited in as groups of four. Testing took place at two adjacent tables each equipped with two laptops and with walls erected out of wood, so players were unable to see each other.

Our paradigm was of a competitive nature and entailed a speeded reaction time game. Each participant was paired anonymously with another participant also playing the game (for similar methods see Steinbeis and Singer, 2013). Money in the form of monetary units (MU; 1 MU = 0.5 Swiss Francs/Euros for Studies 1 and 2 respectively) could be won or lost depending on performance on the reaction-time task (go–nogo; see Fig. 1A). Winning and losing on each trial entailed the addition or subtraction of 4 MUs respectively. Participants were also told if they were faster than their competitor overall, they were eligible for an additional 10 tokens. Participants did not know which of the three others would be their competitor. Participants were instructed to respond as fast as they could whenever a feature of a large blue circle presented on the computer screen changed between 1500 and 4500 ms. Changes comprised features such as the shape (into a triangle or a square), the color (into green or red) or the size (larger or smaller circle). Whenever a change occurred, participants were instructed to press the space bar as fast as possible. The allotted time within which to respond was 1 second. To avoid strategically premature responses, participants were additionally told that while they should respond to changes in shape and size, responses to changes in color should be inhibited. Any such wrong press led to a deduction of MUs. After responding feedback was provided on the screen for 3500 ms and simultaneously the sound of a bell or a buzz was presented for winning or losing respectively via a set of headphones (HD202, Sennheiser electronic GmbH & CO KG, Wedemark Wennebostel, Germany).

Participants began with two blocks of rounds in which they played non-competitively and saw either only their own losses and wins or the competitor's losses and wins (Individual condition). This was followed by two blocks of rounds in which participants saw both their own and their competitor's results simultaneously (Simultaneous condition). Here only results from the Simultaneous condition are reported.

Participants played two blocks of 14 rounds in the Individual and two blocks of 30 rounds in the Simultaneous conditions. Wins and losses were predetermined within the experimental randomization. In the Simultaneous condition there were 6 trials for each condition (i.e. both participants win, both participants lose, one participant wins and the other participant loses) and another 6 no-go trials. Following the performance feedback, participants were given 3500 ms to indicate the emotional state (e.g. happy or sad) by means of a visual analogue scale either of themselves or of the other person ranging from +10 to −10. To do so, participants moved a red star along a horizontal bar towards either a happy or a sad face on each side and with a neutral point in the middle used the left- and right arrow keys to move a little star. Whether to rate themselves or the other was blocked, the order of which was counterbalanced across participants. Importantly, this game was not set up as a zero-sum game in that both participants and competitors could win or lose on each trial. This was implemented by telling participants that success or failure on each trial would be determined by an individually adjusted threshold. Only responses occuring below the threshold would lead to winning on that given trial.

In the self judgment block of the Simultaneous condition experienced envy was assessed contrasting the conditions Self Loss/Other Win – Self Loss/Other Loss and will henceforth be referred to as experienced envy$_{\text{Self Judgment}}$. In the same block experienced Schadenfreude was assessed contrasting the conditions Self Win/Other Loss – Self Win/Other Win and will henceforth be referred to as experienced Schadenfreude$_{\text{Self Judgment}}$. In the other judgment block of the Simultaneous condition attributed envy was assessed contrasting the conditions Self Win/Other Loss – Self Loss/Other Loss and will henceforth be referred to as attributed envy$_{\text{Other Judgment}}$. In the same block attributed Schadenfreude was assessed contrasting the conditions Self Loss/Other Win – Self Win/Other Win and will henceforth be referred to as attributed Schadenfreude$_{\text{Other Judgment}}$. The comparison of these conditions also applies to the contrasts in the imaging analyses. The offline EEB was estimated by measuring the extent of envy and Schadenfreude when participants had to rate themselves as well as the extent to which envy and Schadenfreude were attributed to the presumed competitor when having to rate the other. Thus, crucially, an offline EEB is indicated by a significant correlation between the extent of an experienced emotion and the extent of its attribution to others. Given that the EMOP also allows testing for the presence of an online bias, we ran the full ANOVA with two factors of valence (Positive/Negative) and congruence (Congruent/Incongruent) on the other-judgment run. A significant effect of congruence indicates that one's present state has an influence on how the other emotional state of the other is judged. Importantly however, the direction of this effect indicates if it is an online or offline EEB. Whereas the offline EEB (i.e. attributed Envy and attributed Schadenfreude) look identical to experienced envy and experienced Schadenfreude, the online EEB has the opposite direction in as far as one's own positive affects makes one rate others as feeling happier when they had won (i.e. positive bias) and one's own negative affect makes one rate others as feeling sadder when they had lost (i.e. negative bias).

Study 1b (replicating the EEB)

Participants

Forty-five adults participated in this experiment (24 men; mean age = 23.38 ± 0.16 ± SD years; age range: 20.3–25.5 years). Due to errors in the data recording data of 9 subjects were lost in the other-judgment run.

Procedure

Testing took approximately 1 hour and participants were invited as part of a larger group of up to twenty individuals. Testing occurred at individual work-station equipped with a desk-top computer and walled wooden partitions between each workstation, so that none of the players could see each other.

Details of the paradigm were identical to the ones used in Studies 1 with both presentation of the feedback of wins and losses as well as the duration of rating time fixed at 3500 ms.

Study 2 (manipulation of time)

Participants

Thirty-five adults participated in this experiment (19 men; mean age = 23.79 ± 0.22 ± SD years; age range: 20.23–25.56 years).

Procedure

Testing conditions were identical to Study 1b. Details of the paradigm were identical to Studies 1a and b with the exception that presentation of the feedback of wins and losses was reduced to 1000 ms.

Study 3 (manipulation of direct involvement)

Participants

Thirty-two adults participated in this experiment (16 men; mean age = 23.77 ± 0.48 ± SD years; age range: 19.63–36.69 years).

Procedure

Testing conditions were identical to Studies 1b and 2. Details of the paradigm were identical to the ones used in Studies 1a and 1b, with the exception that in the other-judgment run participants themselves did not actually play the monetary game themselves, but observed two other players and had to indicate their judgment of one of the player's affective state on each trial.

Study 4 (behavioural and MRI)

Participants

We studied 20 adults who participated in the MRI experiment (10 men; mean age = 26.01 ± 2.34 ± SD years; age range: 22–31 years).

Procedure

Scanning was performed over two sessions scheduled to be no more than 1 week apart. The first session entailed a structural scan, followed by two functional runs, one in which subjects saw only their own wins and losses, and another in which subjects only saw the other's wins and losses. This was followed by a behavioural test-battery. The second session entailed two functional runs, in which subjects simultaneously saw their own and the other's pay off. Depending on the run, subjects had to focus on themselves and either indicate how they felt or they had to focus on the other and either indicate how they thought the other felt. The runs were counter-balanced across all subjects. Participants played 20 rounds in each of the single conditions with 10 trials of each type (win and loss) and 20 rounds in each of the Simultaneous condition, with 5 trials of each type (both win, both lose, participant wins and the agent loses and vice versa). To make the interactive set-up more credible, participants were shown a very brief film clip of another participant sitting in a supposedly adjacent room playing the same game simultaneously. Trial length was adjusted by showing a fixation cross for 1500 ms followed by the first stimulus displayed between 1250 and 1750 ms and the subsequent change in stimulus for 1000 ms. Participants were asked to respond within this time. Wins and losses were presented immediately after for 3500 ms, ensued by having to provide a judgment or not for another 3500 ms. This was followed by a jitter period between 2000 and 5000 ms. For the present study only the Simultaneous condition is evaluated.

MRI acquisition

Structural and functional MRI data were acquired on a 3 T Siemens Verio Scanner (Siemens Medical Systems, Erlangen, Germany). Using a 32-channel head coil, high-resolution structural images were acquired using a T1-weighted 3D-MPRAGE sequence (176 sagittal slices. TR = 2300 ms, TE = 2.98 ms, TI = 900 ms, flip angle = 7°, FOV = 256 mm, matrix size = 240 × 256, voxel size = 1 × 1 × 1 mm^3, ipat = 2, 5.10 minutes). Functional MRI data were recorded using T2*-weighted gradient EPI resting-state acquisition with a 12-channel head coil (37 slices tilted at approximately 30° from axial orientation, TR =2000 ms, TE = 27 ms, flip angle = 90°, FOV = 210 mm, matrix size = 70 × 70, voxel size = 3 × 3 × 3 mm^3, 1 mm gap, ipat = 2). Task-based MRI was acquired for 4.5 minutes for an individual run (137 volumes) and 4.8 minutes for a simultaneous run (144 volumes).

Functional MRI processing and analysis

Task-based functional data were analyzed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) on the basis of an event-related model. In brief, functional volumes were slice time corrected and linearly realigned to the first volume to correct for head movements (Friston et al., 1995). The functional image was co-registered with the corresponding structural image, non-linearly registered to the MNI152 template, and finally resampled to a voxel size of 3 × 3 × 3 mm. Normalized images were smoothed using a Gaussian kernel with a full width at half maximum (FWHM) of 8 mm. A high-pass temporal filter with cutoff of 128 seconds was applied to remove low-frequency drifts from the data.

Analysis was carried out according to the general linear model (Friston et al., 1994). Regressors were defined separately for each of the experimental conditions and modeled from the onset of the feedback for a duration of 3.5 seconds. These regressors were convolved with a canonical hemodynamic response function (HRF). Effects of head motion were corrected for by modeling the six motion parameters for each subject as effects of no interest in the design matrix. Subsequent contrast images were derived by applying linear weights to the parameter estimates for the regressor of each event. Contrast images were then entered into one-sample *t*-tests for random effects analyses.

To correct for multiple comparisons, we applied a combined voxel-height and cluster-extent correction using the AlphaSim software of the REST toolbox (Song et al., 2011). AlphSim takes into account the size of the search space (i.e. whole brain) and the estimated smoothness of the images to generate probability estimates (Monte Carlo simulations) of a random field of noise producing clusters of voxels of a given size for a set of voxels passing a given voxelwise *p*-value threshold. The simulations yielded that a FWE-corrected threshold of $p < 0.05$ was achieved with voxels significant at a *z*-value of 2.3 in a contiguous cluster of 70 voxels.

Results

Studies 1a and 1b (establishing and replicating the EEB)

Given the a priori hypotheses we had on the separable effects of envy and Schadenfreude and their respective associations with being attributed to others, we computed separate models for experienced emotions and another for attributed emotions by means of two repeated measures ANOVA with one factor of two levels each (Experienced $envy_{Self\ Judgment}$: Self Loss/Other Win – Self Loss/Other Loss; Experienced $Schadenfreude_{Self\ Judgment}$: Self Win/Other Loss – Self Win/Other Win; Attributed $envy_{Other\ Judgment}$: Self Win/Other Loss – Self Loss/Other Loss; Attributed $Schadenfreude_{Other\ Judgment}$: Self Loss/Other Win – Self Win/Other Win). Given that the EMOP also allows to test for the presence of an online bias, we also ran the full ANOVA with two factors of valence (Positive/Negative) and congruence (Congruent/Incongruent) on the other-judgment run.

Study 1a revealed that our paradigm was indeed capable of inducing strong social emotions. Thus on average our participants showed a significant effect of envy ($F(1,19) = 9.55$; $p = 0.006$, $\eta^2_p = 0.335$; Fig. 2A) as well as a significant effect of Schadenfreude ($F(1,19) = 6.12$; $p = 0.023$, $\eta^2_p = 0.244$; Fig. 2A).

In a second step we tested for the presence of a bias. We found a significant effect of congruence ($F(1,19) = 4.869$; $p = 0.04$, $\eta^2_p = 0.204$). Participants judged the other to feel worse when they themselves had won compared to when they themselves had lost in the domain of the other's loss, thus probably attributing envy to the other ($F(1,19) = 4.54$; $p = 0.047$, $\eta^2_p = 0.193$; Fig. 2B). A comparable, albeit marginally significant effect was found in the domain of the other's gains, whereby participants judged the other to feel better when they themselves had lost compared to when they themselves had won, thus presumably attributing Schadenfreude to the other ($F(1,19) = 4.11$; $p = 0.057$, $\eta^2_p = 0.178$; Fig. 2B).

After having established the direction of the bias, we then tested the hypothesis of the existence of an offline EEB that is whether the degree to which participants experience social emotions is predictive of the extent to which they attribute similar affective states to others. For this purpose we computed the correlations between individual differences in the degree to which subjects actually experienced envy or Schadenfreude in the self runs and the individual differences of the bias in the other runs. And indeed, we found that experienced envy and attributed envy correlated significantly ($r = 0.589$; $p = 0.006$; Fig. 2C). This effect

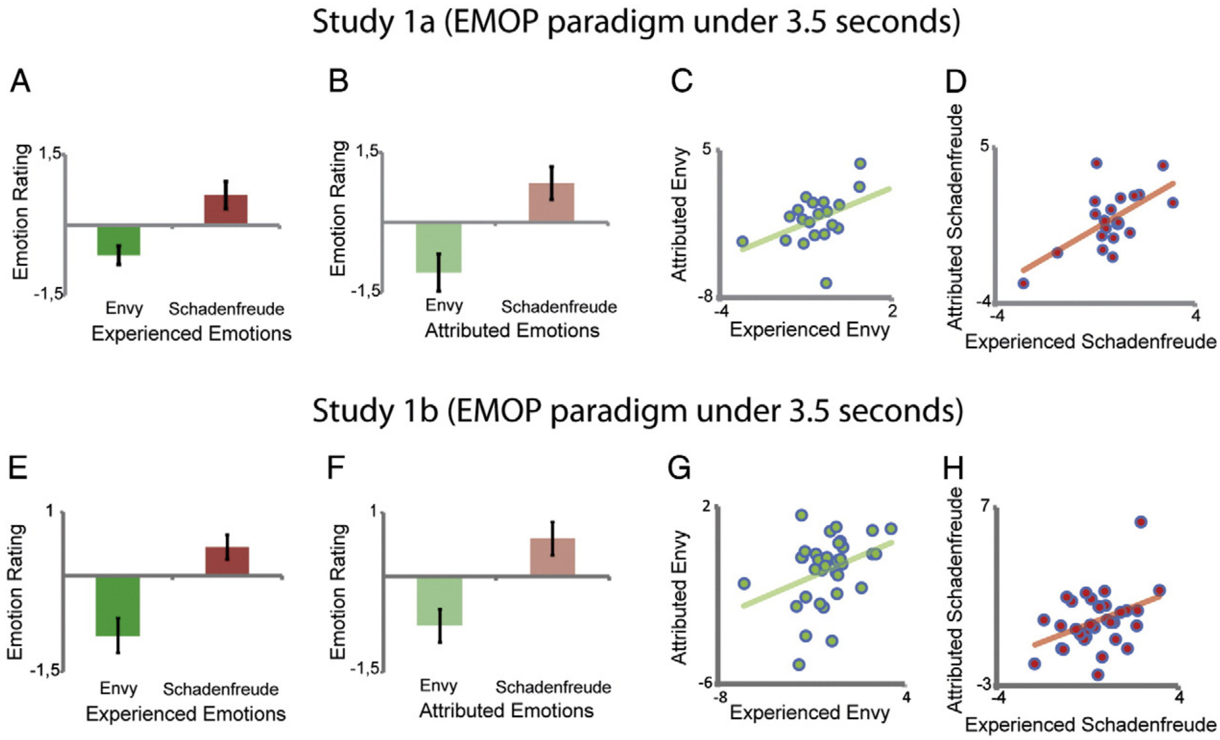

Fig. 2. Behavioural results. Study 1a: (A) Participants showed strong effects of envy ($p = 0.006$) and Schadenfreude ($p = 0.023$) and (B) attributed envy ($p = 0.047$) to the other agent and Schadenfreude marginally so ($p = 0.057$). (C) Individual differences in the experience of envy were positively correlated with individual differences in the attribution of envy ($r = 0.589$; $p = 0.006$). (D) Individual differences in the experience of Schadenfreude were positively correlated with individual differences in the attribution of Schadenfreude ($r = 0.758$; $p = 0.001$). Study 1b: (E) Participants showed effects of envy ($p = 0.001$) and Schadenfreude ($p = 0.027$) and (F) attributed both envy ($p = 0.006$) and Schadenfreude ($p = 0.034$) to the other agent. (G) Individual differences in the experience of envy were positively correlated with individual differences in the attribution of envy ($r = 0.365$; $p = 0.031$). (H) Individual differences in the experience of Schadenfreude were positively correlated with individual differences in the attribution of Schadenfreude ($r = 0.397$; $p = 0.018$).

was mirrored by a similar correlation between experienced Schadenfreude and attributed Schadenfreude ($r = 0.758$; $p = 001$; Fig. 2D).

In Study 1b we sought to replicate these effects. Participants showed a significant effect of envy ($F(1,42) = 11.691$; $p = 0.001$, $\eta^2_p = 0.218$; Fig. 2E) as well as a significant effect of Schadenfreude ($F(1,42) = 5.261$; $p = 0.027$, $\eta^2_p = 0.111$; Fig. 2E). When testing for the presence of a bias we found a significant effect of congruence ($F(1,34) = 10.025$; $p = 0.003$, $\eta^2_p = 0.228$). Thus, like in Study 1a participants presumably attributed envy to the other ($F(1,34) = 8.674$; $p = 0.006$; $\eta^2_p = 0.203$; Fig. 2F). A comparable and this time significant effect was found for the attribution of Schadenfreude ($F(1,34) = 5.162$; $p = 0.034$; $\eta^2_p = 0.132$; Fig. 2F). Crucially, we again show a correlation between experienced envy and attributed envy ($r = 0.365$; $p = 0.031$; Fig. 2G) as well as between experienced Schadenfreude and attributed Schadenfreude ($r = 0.397$; $p = 0.018$; Fig. 2G).

Study 2 (manipulation of time)

In Study 2 we tested whether with EMOP it would be possible to also observe an online EEB as we did in a previous paradigm using pleasant and unpleasant touch (Silani et al., 2013). This previous study also showed that the size of the state-based EEB increases as a function of the time pressure that participants are under. Whereas so far, pay-offs were displayed for 3.5 seconds, this was now reduced to 1 second. In the self-judgment run, we observed only a significant effect of envy ($F(1,34) = 7.78$; $p = 0.009$; $\eta^2_p = 0.186$; Fig. 3A) and none of Schadenfreude ($p > 0.5$; Fig. 3A). However when testing for an effect of congruence in the other-judgment run, we found that this was now significant in the direction predicted by the online EEB ($F(1,33) = 9.335$; $p = 0.004$; $\eta^2_p = 0.221$: Fig. 3B). Thus, while using a time-window of 3.5 seconds we reliably show an offline EEB, this switched to an online EEB when reducing the time within which to process the information and respond.

Study 3 (manipulation of direct involvement)

In this study we tested if the offline EEB requires direct emotional involvement to occur or if offline simulations of how another feels when just observing an interaction between two others are also linked to one's own experience. In the self-judgment run, we could replicate the effect of envy ($F(1,31) = 25.91$; $p = 0.001$, $\eta^2_p = 0.455$; Fig. 3C) and a marginal effect of Schadenfreude ($F(1,31) = 3.08$; $p = 0.092$, $\eta^2_p = 0.089$; Fig. 3C). When testing for the presence of a bias, we found a significant effect of congruence ($F(1,31) = 19.771$; $p = 0.001$, $\eta^2_p = 0.389$), again in the direction congruent to an offline EEB. Participants' attribution of envy ($F(1,31) = 34.69$; $p = 0.001$; $\eta^2_p = 0.528$; Fig. 3D) was significant and the attribution of Schadenfreude marginally so ($F(1,31) = 3.503$; $p = 0.071$; $\eta^2_p = 0.102$; Fig. 3D). The correlations between experienced and attributed social emotions were significant both in the case of envy ($r = 0.43$; $p = 0.014$; Fig. 3E) as well as Schadenfreude ($r = 0.358$; $p = 0.045$; Fig. 3F). These findings suggest that even when not directly involved, participants' judgments of how others feel in the context of the task are still related to how they feel when in that situation, indicating that direct affective engagement is not necessary for the offline EEB to occur.

Study 4 (behavioural and MRI)

In our joint behavioural and fMRI study we could replicate the effect of average first-hand experiences of envy ($F(1,19) = 27.015$; $p = 0.001$, $\eta^2_p = 0.587$; Fig. 3G) as well as Schadenfreude ($F(1,19) = 8.874$; $p = 0.008$, $\eta^2_p = 0.318$; Fig. 3G). To validate whether our differences scores indicative of envy and Schadenfreude

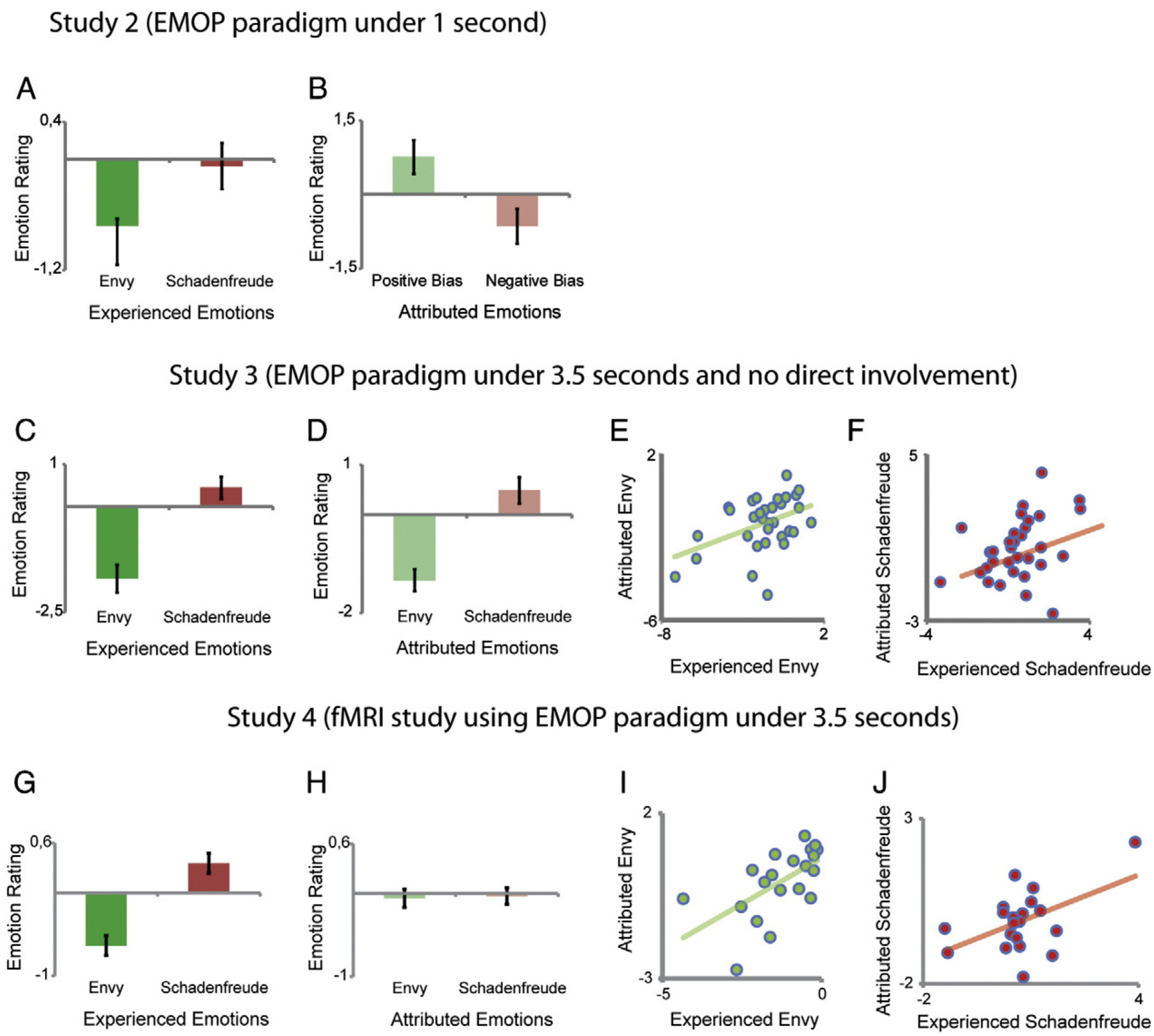

Fig. 3. Behavioural results of Studies 2–4. Study 2: (A) Participants showed strong effects of envy ($p = 0.009$) but not of Schadenfreude ($p > 0.5$). (B) Unlike in Study 1, participants did not attribute envy and Schadenfreude to the other, but judgments were influenced by their immediate states induced by winning and losing, whereby others were judged to feel more positive when participants had won and more negative when participants had lost ($p = 0.004$). Study 3: (C) Participants showed strong effects of envy ($p = 0.001$) and a marginal effect of Schadenfreude ($p = 0.092$) and (D) attributed both envy ($p = 0.001$) and also Schadenfreude albeit marginally ($p = 0.071$) to the other agent. (E) Individual differences in the experience of envy were positively correlated with individual differences in the attribution of envy ($r = 0.43$; $p = 0.014$) and (F) a similar pattern was found for experienced and attributed Schadenfreude ($r = 0.358$; $p = 0.045$). Study 4: (G) Participants showed strong effects of envy ($p = 0.001$) and Schadenfreude ($p = 0.008$) but (H) on a mean level did not attribute these emotions to the other agent ($p > 0.5$). (I) Individual differences in the experience of envy were positively correlated with individual differences in the attribution of envy ($r = 0.596$; $p = 0.006$). (J) Individual differences in the experience of Schadenfreude were positively correlated with individual differences in the attribution of Schadenfreude ($r = 0.5$; $p = 0.025$).

concord with subjective reports of these emotions, we also asked participants in a post-imaging questionnaire the extent to which they experienced envy and Schadenfreude on a scale from 1 to 5, 5 indicating the maximum. Participants reported a mean level of 3.75 of envy (significantly different from 1: $t(19) = 10.564$; $p < 0.001$) and a mean level of 3.7 of Schadenfreude (significantly different from 1: $t(19) = 9.677$; $p < 0.001$). These data suggest that our task reliably measures social emotions of envy and Schadenfreude in adults. Further, effects of Schadenfreude and envy persisted even after controlling for responses to wins and losses respectively in the individual condition (Schadenfreude: $F(1,18) = 7.394$; $p = 0.014$, $\eta^2_p = 0.291$; envy: $F(1,18) = 22.03$; $p = 0.001, \eta^2_p = 0.552$). Also, there was no correlation between individual differences in responses to wins and losses and Schadenfreude and envy respectively ($r < 0.32$; $p > 0.16$).

When testing for the attribution of feelings of envy and Schadenfreude on the average level of main effects, we found neither an effect of attributed envy nor an effect of attributed Schadenfreude ($F < 0.3$; $p > 0.5$; Fig. 3H). More importantly, however, when testing again for the presence of an offline EEB by looking at the extent to which the attribution of envy and Schadenfreude was linked to the first-hand experience of these social emotions in the self condition, there was a significant correlation between experience and attribution of envy ($r = 0.596$; $p = 0.006$; Fig. 3I) and for the experience and attribution of Schadenfreude ($r = 0.5$; $p = 0.025$; Fig. 3J).

The behavioural findings suggest that in the context of social emotions, there is a tight coupling between the extent to which we experience an emotion and the extent to which this is attributed to others. If shared networks are accountable for this offline EEB, then we would expect to see that the same neural structures for the experience and the attribution of a social emotion are recruited. Crucially, we would expect that individual differences in neural activation of these shared networks for the experience of an emotion are predictive of the extent to which these networks are activated during the attribution of social emotions.

We looked at separate contrasts for envy and Schadenfreude and for experienced emotions we computed these for conditions only in the self judgment runs whereas for attributed emotions these were computed for conditions in the other judgment runs. The contrasts were thus as follows: for experienced $\text{envy}_{\text{Self Judgment}}$: SelfLossOtherWin > SelfLossOtherLoss; for experienced $\text{Schadenfreude}_{\text{Self Judgment}}$: SelfWinOtherLoss > SelfWinOtherWin; for attributed $\text{envy}_{\text{Other Judgment}}$: SelfLossOtherLoss > SelfWinOtherLoss; for attributed $\text{Schadenfreude}_{\text{Other Judgment}}$: SelfWinOtherWin > SelfLossOtherWin.

Experienced emotions

For the contrast of experienced envy we observed activation of the left anterior insula ($x = -30, y = 20, z = -11$; Fig. 4A) as well as the dorsal medial prefrontal cortex, extending into anterior cingulate cortex ($x = -6, y = 59, z = 7$; Fig. 4B). For effects of experienced Schadenfreude we saw activation (all at $p_{\text{fwe}} < 0.05$) of medial prefrontal cortex comprising both dorsal and ventral portions ($x = -12, y = 68, z = 13$; Fig. 4C), the posterior cingulate cortex ($x = -9, y = -49$ $z = 22$; Fig. 4C), left striatum ($x = -6, y = 2, z = -2$; Fig. 4D) as well as right striatum ($x = 9, y = 5, z = 10$; Fig. 4D), left temporal pole ($x = -60, y = -7, z = -29$), left middle temporal gyrus ($x = -57, y = -19, z = -2$) and right occipital cortex ($x = 18, y = -94, z = 10$).

Attributed emotions

For the contrast of attributed envy we observed activation of the left anterior insula ($x = -33, y = 17, z = 4$) as well as the anterior cingulate ($x = -9, y = 35, z = 25$) and the right anterior insula ($x = 42, y = 14, z = 1$). For the contrast of attributed Schadenfreude we observed activation of the dorsal medial prefrontal cortex ($x = 12, y = 53, z = 16$).

Shared networks of experienced and attributed emotions

We then sought to see which of these specific brain areas involved in experienced envy and Schadenfreude are also engaged in the attribution of these emotions to others in the other-judgment run. To this end, we computed a conjunction analysis for the contrast of experienced envy with that of attributed envy. We found significant involvement of left anterior insula ($x = -30, y = 17, z = -11$; Fig. 4E) as well as anterior cingulate cortex ($x = -6, y = 50, z = 4$; Fig. 4F). To assess shared networks in the domain of Schadenfreude, another conjunction was computed for the contrast of experienced Schadenfreude and attributed Schadenfreude. We found significant involvement of the dorsal medial prefrontal cortex ($x = 3, y = 47, z = 22$; Fig. 4G) but not for the ventral striatum, not even at lowered thresholds. In sum, for envy and partly for Schadenfreude we could indeed show that areas involved in the first-hand experience of social emotions are also recruited when vicariously attributing these emotions to others.

Linking neural mechanisms of experienced and attributed emotions

A crucial test to establish whether shared networks function as the neuronal basis underlying offline EEB is to see whether individual differences in the attribution of envy and Schadenfreude also recruit those brain regions modulated by individual differences in the experience of these emotions. Thus, we found that activity in left anterior insula for the contrast of experienced envy was positively correlated with individual differences in reported envy ($x = -27, y = 26, z = -2$; Fig. 5A). Individual differences in experienced Schadenfreude did not significantly correlate with any brain region. Further, we found that in the contrast for attributed envy individual differences in the attribution of envy significantly modulated activity in the left anterior insula

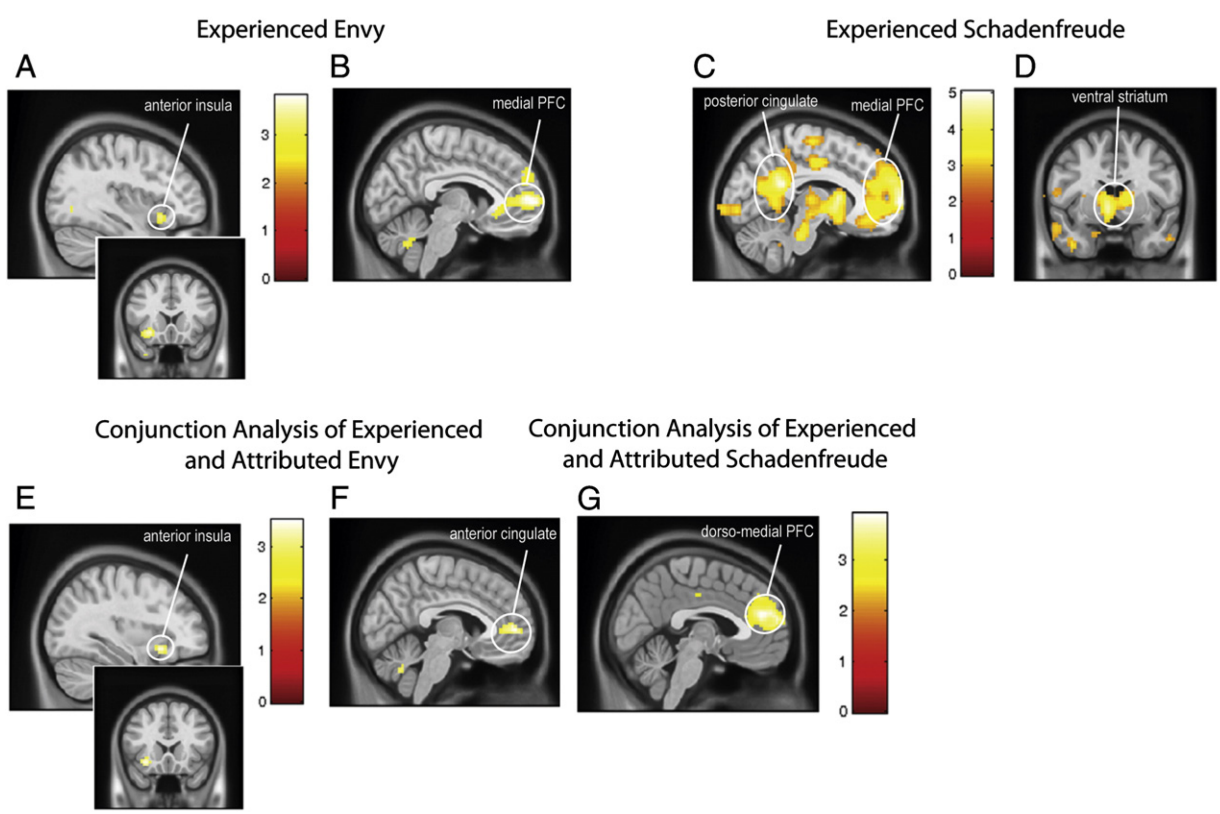

Fig. 4. fMRI results (all at $p_{\text{fwe}} < 0.05$; thresholded at $p < 0.005$ uncorrected for purposes of illustration). When participants lost and they saw the other agent win compared to also lose (i.e. experiencing envy) there was significant activation of (A) left anterior insula and (B) anterior cingulate cortex. When participants won and they saw the other agent lose (i.e. experiencing Schadenfreude) compared to also win there was significant activation of (C) medial prefrontal cortex, posterior cingulate cortex and (D) bilateral striatum. When computing a conjunction analysis between runs when participants had to judge themselves after losing and seeing the other agent win compared to lose (i.e. experienced envy) with runs when participants had to judge the other after seeing them lose while the participant had won compared to also lost (i.e. attributed envy), there was a significant overlap in (E) left anterior insula as well as (F) anterior cingulate cortex. When computing a conjunction analysis between runs when participants had to judge themselves after winning and seeing the other agent lose compared to also win (i.e. experienced Schadenfreude) with runs when participants had to judge the other after seeing them win (i.e. attributed Schadenfreude) while the participant had lost compared to also won, there was a significant overlap in (G) dorso-medial prefrontal cortex.

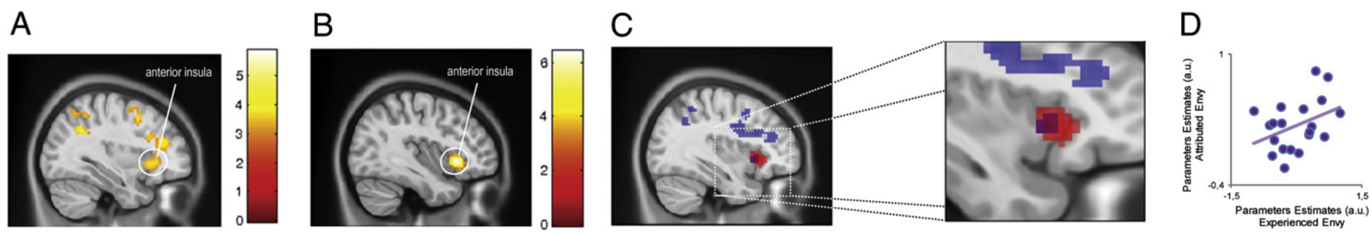

Fig. 5. fMRI results (all at $p_{fwe} < 0.05$; thresholded at $p < 0.005$ uncorrected for purposes of illustration). (A) Individual differences in envy were positively correlated with activity in the left anterior insula in the contrast for experienced envy. (B) Individual differences in the attribution of envy were positively correlated with activity in the left anterior insula in the contrast for attributed envy. (C) There was a significant overlap in voxels in the anterior insula that were sensitive to individual differences in experienced envy in the contrast of experienced envy (blue) and individual differences in the attribution of envy in the contrast of attributed envy (red). (D) There was a significant correlation in the extent to which the anterior insula was recruited in the contrast of experienced envy and in the contrast of attributed of envy ($r = 0.386$; $p = 0.046$, one-tailed).

($x = -39$, $y = 20$, $z = -2$; Fig. 5B). No modulation of brain activity for the contrast of attributed Schadenfreude by individual differences in the attribution of Schadenfreude was found. While there was a significant overlap between the modulation of left anterior insula by individual differences in the experience of envy in the self-judgment run and individual differences in the attribution of envy in the other-judgment run (Fig. 5C), this was not the case for Schadenfreude.

Finally, we sought to test if the extent to which anterior insula is recruited during the experience of envy is predictive of anterior insula activity during its attribution to others. We therefore extracted parameter estimates from the contrast of experienced envy using a mask from the contrast of attributed envy (set at $p < 0.001$) and vice versa. This ensured independence of the analyses. Indeed we found a significant correlation between activation of the anterior insula during the experience of envy and its attribution ($r = 0.386$; $p = 0.046$; one-tailed; Fig. 5D).

Discussion

The present set of behavioural and neuroimaging studies sought to examine the conditions for the occurrence of online and more importantly an offline EEB, as well as the neuro-cognitive mechanisms underlying offline bias. More specifically, we employed a speeded reaction time task, the EMOP, associated with winning and losing money while playing with another agent. This task is capable of eliciting strong social emotions arising out of social comparisons, namely envy and Schadenfreude. Importantly, the EMOP requires sometimes judging one's own experienced feelings while winning and losing and sometimes what the other agent may feel in comparable situations. Regarding the empathic judgments about the others' feeling states, the resulting bias could take the form of an online bias. This entails the immediately experienced affective state (i.e. positive or negative) of the participants elicited through winning or losing influencing the judgment of the other in that same direction. Alternatively, the empathic ratings could also take the form of an offline bias. This entails attributing to others the experience of envy and Schadenfreude to the same extent to which one would have been likely to experience those being in a similar social comparison situation (see Fig. 1). The present paradigm was designed in such a way that the direction of the online and offline EEBs is directly opposed. In our first set of behavioural experiments we aimed at showing first-time evidence for the presence of such an offline EEB in the domain of social emotions such as envy and Schadenfreude and to study the conditions under which online as opposed to offline EEB are likely to occur. In our last imaging experiment we investigated the neural mechanisms underlying such an offline EEB.

We could reliably show the occurrence of an offline EEB, as indicated by mean differences in the direction predicted by the presence of an offline EEB and more importantly by strong and significant correlations between the first-hand experience of these social emotions and the attribution of envy and Schadenfreude onto others. This offline EEB repeatedly emerged across experiments 1a, 1b, 3 and 4 when sufficient time was given to process one's own and the other's emotional state. When reducing this time interval from 3 to 1 second, an online bias was observed instead (Study 2). Thus, there appears to be a clear temporal unfolding of affective egocentricity, whereby when time pressure is high, we appear to simply project our current affective states onto others (e.g. online EEB; Silani et al., 2013). When given more time however we engage in a more demanding process which requires the internal "offline" simulation of what we would experience ourselves in a similar social comparison situation (e.g., offline EEB). Interestingly, previous work could show that children aged 6 to 13 years of age show a strong online EEB when using the same paradigm as in this study under the long 3 second conditions (Steinbeis et al., in press) and compared to adults these age differences could be explained by the functional immaturity of those brain regions required to overcome such an online EEB. Thus, future studies may focus on identifying the developmental conditions under which such an online bias develops into an offline bias.

Study 3 provides the crucial piece of evidence of the offline nature of the offline EEB. Thus, in Study 3 direct emotional involvement was not required for the occurrence of an offline EEB and the degree to which one attributes envy or Schadenfreude to a 3rd party was still correlated with one's own tendency to experience such social emotions in similar situations. This suggests that empathic judgments resulting in an offline EEB are presumably not made on the basis of an externally stimulated current affective state but rather made on the basis of offline internal affective simulations which in turn can only occur when there is sufficient time to do so.

Another goal was to explore the neuronal mechanisms underlying offline EEB (Study 4). Here we were particularly interested in extending previous shared network accounts of empathy (Bernhardt and Singer, 2012; Jabbi et al., 2008; Keysers et al., 2004; Lamm et al., 2011; Mobbs et al., 2009; Singer, 2012; Singer et al., 2004; Wicker et al., 2003) to the domain of higher-order social emotions such as envy and Schadenfreude. More importantly we aimed to test whether individual differences in the activation levels underlying the first-hand experience of such social emotions were able to predict the degree to which these areas are active when making in empathic judgements. Thus, whereas previous studies have provided converging evidence that rSMG is crucially involved in overcoming EEB (Silani et al., 2013; Steinbeis et al., in press) here we wish to test what neural mechanisms give rise to EEB in the first place.

Indeed the neuroimaging findings from Study 4 could show that the experience of envy and Schadenfreude activates a circumscribed set of brain regions, such as the left anterior insula and anterior cingulate cortex for envy (Takahashi et al., 2009) and medial prefrontal cortex and the striatum for Schadenfreude (Bault et al., 2011; Dvash et al., 2010; Singer et al., 2006; Takahashi et al., 2009), which were also differentially activated when attributing these specific emotions to others. In line with this observation are previous studies demonstrating that when imagining how others feel, we draw on the same neural representations of our own emotional experience in the context of pain (Lamm et al., 2011; Singer et al., 2004, 2006), primary touch (Keysers et al., 2004), disgust (Wicker et al., 2003) and reward (Mobbs et al., 2009). We extend this to show that such mechanisms are also at work for higher level social emotions (Krach et al., 2011) that arise out of social comparison, such as such as envy and Schadenfreude.

Most importantly, however, we show that at least in the case of envy, the same portion of the anterior insula was sensitive both to individual differences in the degree to which one experiences envy and to which one attributes envy to others in a similar situation. Thus, the degree of anterior insula recruitment during the experience of envy was predictive of how strongly this region was activated during the attribution of envy to others. These findings provide first evidence for a neural mechanism explaining the occurrence of offline EEB. By demonstrating that previously shown shared networks underlying both our first-hand as well as vicarious experience of emotions are also sensitive to correlations between individual differences of first-hand experienced and attributed emotions provides an explanation for why empathic judgments automatically become skewed towards one's own set of experiences and lead to emotional egocentricity. Our prediction is that such a mechanism holds for all types of emotional egocentricity irrespective of the type of emotion experienced.

Importantly, we show that we observe brain regions that are typically involved in empathizing with the affective experience of others and not mental state attribution, which underlie the offline EEB. There is by now considerable evidence that there are different routes of social cognition underlying the inference of intentions, beliefs or thoughts on the one hand or feelings and emotions on the other (Frith and Frith, 2010; Singer, 2006). Thus, for instance specific parts of medial PFC are activated when making personality judgments of similar or dissimilar others (Mitchell, 2009; Mitchell et al., 2006). Further, when making attributions of others beliefs and mental states cortical midline structures and TPJ are recruited (Amodio and Frith, 2006; Saxe and Powell, 2006). Finally, when making judgments of other's emotional states we rely on brain regions that are also activated when we experience these emotions ourselves such as the anterior insula in the context of pain (Bernhardt and Singer, 2012; Singer et al., 2004) as well as disgust and unpleasant taste (Wicker et al., 2003) and the ventral striatum in the case of joy (Mobbs et al., 2009). This suggests that the brain is highly attuned to the type of judgment that has to be made (i.e. personality attributes, mental content, emotional states) and the reason why we show a circumscribed network of brain regions such as the anterior insula for the attribution of envy is because it also represents the emotional experience of envy. In contrast, our task does not involve the attribution of beliefs or other cognitive mental states.

Our finding of a specific role of the anterior insula in experiencing envy and attributing it to others may surprise in as far previous studies purporting to investigate envy did not report activity in this region (Bault et al., 2011; Dvash et al., 2010; Takahashi et al., 2009). Instead conditions where envy was likely to occur selectively modulated activity in the ventral striatum (Bault et al., 2011; Dvash et al., 2010). This discrepancy in findings may in part result from differing methodologies and future studies should try to obtain convergence by comparing behavioural and neural responses across tasks within the same participants. At least in the present case, the observed association between individual differences in the experience of envy and activity in the anterior insula, lends strong support to the present interpretation, that anterior insula is involved in the affective aspects of envy. These findings can be reconciled given the important role of the anterior insula in processing highly arousing stimuli and particularly negative affect (Etkin and Wager, 2007). Thus, the present findings extend recent models of the social function of the anterior insula (Lamm and Singer, 2010; Singer et al., 2009; Zaki et al., 2012) to include coding for social emotions such as envy, both one's own as well as of others.

Whereas previous studies have shown particularly the ventral striatum to be sensitive to such individual differences in Schadenfreude (Singer et al., 2006; Takahashi et al., 2009), no such association was found in the present study. Other studies have shown that empathic neuronal responses in the ventral striatum to others' wins (Mobbs et al., 2009) and to an outgroup member receiving pain (Hein et al., 2010) were modulated by perceived similarity to the target and personal impression of the outgroup member respectively. This suggests that the involvement of the striatum in the experience of positive social emotions such as vicarious joy or Schadenfreude is sensitive also to individual differences in how others are perceived, something that was not assessed in the present study. Future fMRI studies with bigger samples and inclusion of mediator variables may help shed light on this issue.

It is important to note that the present effects were observed in the context of interactions between strangers. Whereas in Studies 1 and 3 participants sat either next to or opposite each other, in the fourth study, participants were merely shown a video of another in a room and had no further personal contact. As such, and in the absence of any other information on whom the judgment is being made on, using one's own affective experience to make a judgment would appear to be the best heuristic. It has been shown that humans believe others to be similar to them irrespective of whether they believe someone to be from an in- or an outgroup, but it is in fact stronger for people they believe to be similar to them (for a meta-analysis see Robbins and Krueger, 2005). Whereas we cannot know from the present studies whether participants assumed by default that anonymous others will be similar to them, it is likely that such a heuristic mediated the presently observed effect of the occurrence of an offline EEB and thus we assume that these results will very likely generalize to a whole range of social interactions and social partners. Whether this is adaptive and how flexibly such a bias can be attuned to contextual and personal information remains to be seen and will require further study. Future studies may also wish to assess the extent to which these egocentric biases persist in the face of concrete information of another's emotional experience and how emotional egocentricity and empathic accuracy might be linked. Further, the extent to which the presence of the offline EEB is linked to the projection of one's emotional traits (i.e. trait envy) remains an open question that merits further research.

Conclusion

In conclusion the present set of studies introduces the existence of an offline emotional egocentricity bias in social judgments by showing that healthy human adults indeed tend to attribute their own tendencies to display social emotions such as envy and Schadenfreude in social comparison situation to others. This offline EEB however is dependent of time available for such judgments. Thus, we show that a slight temporal modification of our paradigm is capable of transforming an offline EEB into an online EEB, whereby the influence of one's immediate affective state dominates under time pressure leading to an online EEB. Crucially, we show that the process of simulation underlying the offline EEB occurs by means of recruiting the same brain regions engaged also in the first-hand affective experience of such social emotions. This was buttressed by individual differences in the experience and in the attribution of envy modulating the same part of the anterior insula when judging oneself or another respectively. Given the considerable costs of interpersonal misunderstandings that can result from affective egocentricity, isolating the mechanisms that lead to several distinct manifestations of such socio-affective biases can help to devise measures which reduce the likelihood for either one of these false judgments to occur and therefore impact of this potentially detrimental human proclivity.

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