

Reappraising the Ultimatum: an fMRI Study of Emotion Regulation and Decision Making

Alessandro Grecucci^{1,2}, Cinzia Giorgetta^{1,2}, Mascha van't Wout³, Nicolao Bonini¹ and Alan G. Sanfey^{1,2,4,5}

¹Department of Cognitive Science and Education, University of Trento, Corso Bettini 31 I-38122, Rovereto, Italy, ²Center for Mind Brain Sciences, University of Trento, via Belenzani, 12 I-38122 Trento, Italy, ³Department of Cognitive, Linguistic and Psychological Science, Brown University, 89 Waterman Street & 229 Waterman Street, Providence, RI 02912, USA, ⁴Department of Psychology, University of Arizona, 1503 E University Blvd, Tucson, AZ 85721, USA and ⁵Donders Institute for Brain, Cognition and Behavior, Radboud University, Montessorilaan 3 6525 HR Nijmegen, The Netherlands

Address correspondence to Alessandro Grecucci, Department of Cognitive Science and Education/Center for Mind/Brain Sciences, Corso Bettini 31, Rovereto, Trentino, 38068 Italy. Email: alessandro.grecucci@unitn.it

Emotion regulation strategies provide a means by which to modulate our social behavior. In this study, we investigated the effect of using reappraisal to both up- and downregulate social decision making. After being instructed on how to use reappraisal, participants played the Ultimatum Game while undergoing functional magnetic resonance imaging and applied the strategies of upregulation (reappraising the proposer's intentions as more negative), down-regulation (reappraising the proposer's intentions as less negative), as well as a baseline "look" condition. As hypothesized, when reappraising, decision acceptance rates were altered, with a greater number of unfair offers accepted while down-regulating and a greater number of unfair offers rejected while upregulating, both relative to the baseline condition. At the neural level, during reappraisal, significant activations were observed in the inferior and middle frontal gyrus (MFG), in addition to the medial prefrontal cortex and cingulate gyrus for unfair offers only. Regulated decisions involved left inferior frontal gyrus for upregulation and MFG for down-regulation strategies, respectively. Importantly, the effects of emotion modulation were evident in posterior insula, with less activation for down-regulation and more activation for upregulation in these areas. Notably, we show for the first time that top-down strategies such as reappraisal strongly affect our socioeconomic decisions.

Keywords: decision making, emotion regulation, mentalizing, reappraisal, Ultimatum Game

Introduction

Standard economic theory predicts that people will behave in a largely self-interested fashion when interacting with others. However, a considerable amount of recent experimental work has demonstrated that players are often influenced by factors beyond their narrow financial self-interest. A case in point is behavior in the Ultimatum Game (UG, Guth et al. 1982). Here, 2 players have the opportunity to split a sum of money. One player, the proposer, makes an offer as to how this money should be split. The responder must then make a decision to either accept or reject this offer. If the offer is accepted then the money is split as proposed, but if the responder rejects the offer then neither player receives anything. Of particular interest is the well-replicated result that low offers are rejected approximately 50% of the time (Camerer 2003). That is, players' choices in the UG are not purely driven by financial self-interest but rather are guided by a subjective interpretation of the social interaction, with evidence that negative emotions play an important role in punishment behavior (Pillutla and Murnighan 1996; Xiao and Houser 2005). Neuroimaging work has demonstrated that the anterior insula, an area often

implicated in somatosensory representation, is more active for unfair offers, with this activity tracking the decision to accept or reject (Sanfey et al. 2003). Furthermore, several groups have recently shown that manipulating the emotional state of participants can significantly alter UG decision making (Harlé and Sanfey 2007; Moretti and di Pellegrino 2010). These results demonstrate that even subtle incidental negative emotions can play an important role in biasing decision making, likely due to their power to change the way participants mentalize about the social interaction (Frith et al. 1991; Wagner et al. 2011). Indeed, the role of emotion has been incorporated in recent dual-process models of decision making (van't Wout et al. 2010; Koenigs and Tranel, 2007; Sanfey 2007), though exactly how cognitive and emotional systems interact is still unclear. It seems evident that the social context and, in particular, negative emotions play a role in decision making in general, and in interactive tasks like the UG specifically, however, it is still largely unknown how these processes interact with deliberative systems and if they can be controlled in a "top-down" fashion.

A useful approach to investigate this question is to examine if players in these social interactive scenarios have the ability to alter their decisions by exerting effort to modulate the elicited negative emotions. Although there is relatively little work on the link between top-down control of emotions and decision making, the experimental use of emotion regulation strategies has the potential to greatly elucidate this relationship.

Emotion regulation refers to a set of different strategies by which "individuals influence which emotions they have, when they have them, and how they experience and express these emotions" (cf. Gross 1999). The relevance of emotion regulation to interactive decision making is suggested by recent neuropsychological studies demonstrating that lesions in brain areas implicated in negative emotional regulation result in increased rejections of unfair offers (Koenigs and Tranel 2007; Moretti et al. 2009). Additionally, in individual decision-making tasks, Sokol-Hessner et al. (2009) showed that "thinking like a trader" resulted in changes in preferences when participants were trained to use a strategy to reframe their role in an economic transaction. Another study (Staudinger et al. 2009) asked participants to reappraise (in the form of "distancing," i.e., to detach oneself from feelings and behave as a neutral observer) economic stimuli such as gains or losses in a monetary reward task, finding an attenuation of expected value and a modulation of outcome valence in the striatum. In the same fashion, Martin and Delgado (2011) showed a modulation of the striatum and a reduction of risky choice behavior in a gambling task when participants regulated their

emotions following a simple instruction (“try to think of a calming scene”).

Previous studies on emotion regulation using simple emotional pictures (International Affective Picture System, IAPS, Lang, Bradley, Cuthbert 2008) have shown an increase in activation of the prefrontal cortex (dorsolateral prefrontal cortex, DLPFC) when applying a regulation strategy (Ochsner et al. 2002; Staudinger et al. 2009). One possibility is that there is a specific region commonly activated across tasks, independent from the particular emotion-inducing stimuli used. The first question we will address with the present study is whether the area of prefrontal cortex shown to be responsible for regulating emotions stemming from simple emotional pictures is also active for emotions derived from social interactive decision making. This question is important, as it will potentially further elucidate the role of DLPFC and its ability to modulate responses to a wide variety of stimuli and situations. To address this, we will look at the main effect of strategy, that is, the brain differences between employing a regulation strategy and not employing one. A related question is whether the effect of strategy is independent from the type of offer made and the subsequent decision. To answer this, separate contrasts will be computed for the effect of strategy for each trial type (fair and unfair offers, respectively). If a region is involved in emotion regulation strategies, we may also find some connection with behavioral measures. Additionally, we will also examine the relationship between brain measures in the UG and other behavioral measures to assess the likely use of these strategies in everyday life (by using scales such as the Emotional Regulation Questionnaire [ERQ]; Gross and John 2003, for example). To address this, we will examine brain signal change in key regions of interests and how this in turn correlates with behavioral measures.

Despite their importance, the previous studies outlined above focused their attention primarily on individual decision making, examining factors such as loss aversion, reward, and expected value. Therefore, it is still unknown whether (and, perhaps more importantly, how) negative emotions stemming from social interactive decision making may be subject to regulation and lead to subsequent changes in decision behavior. In a recent behavioral study, our group demonstrated that participants in an emotional reappraisal condition (down-regulation) accepted unfair UG offers at a greater rate than those in a no-regulation condition (van't Wout et al. 2010), providing a useful first indication of how emotions are regulated during interactive decision making. Despite this encouraging result, some issues still remain. For example, this study (and others) demonstrated that decisions can be affected by down-regulating emotions, but no test of upregulation was conducted. This is important, as reappraisal is used not merely to subjectively improve bad situations, but can also be used to make bad situations feel worse. In some cases, cognitively upregulating negative emotion may be desirable (Ochsner et al. 2004), as when players reconsider an unequal offer to be even more unfair. In line with previous work on this topic (Ochsner et al. 2004), we define upregulation as the interpretation of intentions, behavior, and their outcomes as more negative (things are getting worse) and down-regulation as the interpretation of intentions, actions, and their outcomes as less negative (things are getting better). To date, the effect of upregulation on decision making has not been examined. Modulating our emotions, and in turn modulating our subsequent decisions, may play a vital role when cooperating and

reciprocating with other individuals in daily interactions, and therefore, a more complete account of how this process operates would be useful. Here, we aimed to extend the behavioral results from van't Wout et al. (2010), by exploring both up- and downregulation effects within participants. This allows us to explore whether the negative emotions induced by an unfair Ultimatum offer can be both reduced and increased depending on the manipulation and whether this is then reflected in the decision to punish the other player for the unfairness. We hypothesized that we would observe lower rejection rates of unfair offers when asked to downregulate, as we have found previously, but additionally see higher rejection rates when asked to upregulate, both conditions as compared with baseline.

We will explore this by looking separately for the effects of regulated down and up decisions. These contrasts will look at specific regions responsible for each of the 2 reappraisal strategies when rejecting more (as a consequence of upregulation) or rejecting less (downregulation) of the offers. One possibility is that the processes underlying the decrease or increase of emotions are coded in 2 or more different brain structures.

This behavioral result would further confirm and extend the interaction between affective and deliberative systems in decision making, as suggested by dual-system accounts (Sanfey and Chang 2008). These models distinguish between a System 1, described as automatic, fast, unconscious, emotional, and slow learning, and a System 2, described as controlled, slow, conscious, affectively neutral, and fast learning. Here, we aim to further explore the way in which cognitive strategies interact and subsequently alter decision making in a socioeconomic context. Moreover, this approach may help to better understand the specific emotions involved when regulating. We hypothesize that, in line with previous work (Pillutla and Murnighan 1996), anger may be the target emotion involved in UG and the one modulated by the reappraisal strategy.

A final important question, we address is whether emotion regulation applied to social decision making shares the same brain areas as involved in regulating either simple visual stimuli (IAPS, Ochsner et al. 2002, 2004), or in individual decision making (Sokol-Hessner et al. 2009; Staudinger et al. 2009; Jarcho et al. 2011; Martin and Delgado 2011). Studies investigating the neural basis of emotion regulation have demonstrated that the reappraisal of emotions is associated with the modulation of key regions processing specific emotions, such as the amygdala, striatum, or orbitofrontal cortex. Sanfey et al. (2003) proposed the involvement of anterior insula and DLPFC in response to unfair offers in the UG, such that greater activation of the anterior insula, a brain area associated with the processing of aversive emotions such as anger and disgust (Phillips et al. 1997), was associated with the rejection of unfair offers. Thus, one potential hypothesis is that up- and downregulation in social interactive decision making (UG) could recruit the insula (effects of modulation). This would be a confirmation of the role of insula in emotional reactivity when receiving unfair offers. If the insula demonstrates modulated activity, this could be considered strong support for its role in emotional reactions in the UG. To test this hypothesis, we will look at regions modulated by the respective strategies (i.e., showing a linear increase in activity: Down < Look < Up).

In summary, the present study can yield interesting and important new insights into both whether and how emotion regulation strategies can influence behavior in a well-characterized social interactive decision-making task.

Materials and Methods

Participants

Twenty-one participants (11 males, mean age: 23.5 ± 3.6 years) participated in the study. Participants had normal or corrected to normal vision and had no history of psychiatric, medical, or neurological illness, as verified by a semistructured interview by a physician. All participants provided written informed consent, as approved by the local ethical committee, and were paid 35 euros for participation.

Behavioral Paradigm

The paradigm comprised a general cognitive and emotional assessment (described below), followed by training and testing in emotion regulation techniques. Then, they underwent scanning with functional magnetic resonance imaging (fMRI) while playing rounds of the UG under conditions of emotion regulation. Finally, there was a debriefing phase.

Assessment

In the assessment phase, participants filled out a series of self-administered questionnaires. These comprised the Positive and Negative Affective scales (Watson et al. 1988); the behavioral inhibition and the behavioral activation scales (Carver and White 1994); the Interpersonal Reactivity Index (Davis 1980); and, of primary interest for the present study, the ERQ (Gross and John 2003).

Training and Testing

In the training phase, participants were specifically trained in reappraisal strategies by the experimenter. To begin, participants were introduced to the term reappraisal as a way whereby people in daily life may reinterpret an event by changing its meaning. They were told that interpreting an event as more negative can make that event even more negative in their eyes, while interpreting it as less negative can decrease its negativity accordingly. In line with previous research on this topic (Ochsner et al. 2004), we define upregulation (“increase”

strategy) as “the interpretation of the situation, event, or people’s intentions and behaviors as more negative” and downregulation (“decrease” strategy) as “the interpretation of the situation, event, or people’s intentions and behaviors as less negative,” and the “look” condition as one where the participant should perceive the situation spontaneously without any effort to reinterpret. Participants were given an example of a common negative situation and how it can be reinterpreted (reappraised) in such a way as to make it either more or less negative. Thus, in the case of a crying woman (as shown in Fig. 1A), the “increase” strategy might involve imagining that the woman is in great pain because she is mourning a loved one’s death. In contrast, the “decrease” condition might involve imagining that the woman is merely tired or suffering from a headache. For the “look” condition, they were to simply allow themselves to respond naturally without any effort of interpretation. Importantly, this reappraisal training was not focused on giving instructions “what” to think for each situation but rather “how” to rethink the stimulus by manipulating the main variables (intentions and behaviors) in either a more or less negative way. To ensure participants understood the instructions and were successfully applying the required reappraisal strategies, they were asked to reappraise while viewing pictures from the IAPS picture set (Lang et al. 2008). Eighteen unpleasant IAPS pictures were selected and divided into 3 subsets to be used across the reappraisal conditions (up, down, and look). The 3 subsets were selected to have standardized ratings balanced across both valence (2.68, 2.55, and 2.60, respectively) and arousal (5.2, 5.36, and 5.37) (Lang et al. 2008), with these subsets not differing significantly on valence (subset 1 vs. 2, $P = 0.80$; subset 1 vs. 3, $P = 0.79$; subset 2 vs. 3, $P = 0.93$) or on arousal (subset 1 vs. 2, $P = 0.88$; subset 1 vs. 3, $P = 0.83$; subset 2 vs. 3, $P = 0.98$) using two-sample t -tests.

After a picture was presented for 5 s, participants rated it according to valence and arousal dimensions using the Self Assessment Manikin procedure (Lang 1994) (see Fig. 1A). After participants completed this task, they were asked to give an example of their interpretation for 2 IAPS pictures. If the experimenter was satisfied by the reappraisal strategies used (using the criteria of interpreting the stimuli as more or less negative), the participants were introduced to the last part of the training, the UG.

Here, instructions were first given as to the nature of the UG. The task instructions emphasized that the different partners in the game would play the game independently of each other, and participants were led to believe the games would be played for real with the set of partners they saw. After this information, participants were given instructions as to how to apply reappraisal in the context of the UG. In the UG-training phase, each participant played 3 practice rounds of the UG, twice in which they were asked to reappraise (once for each of the

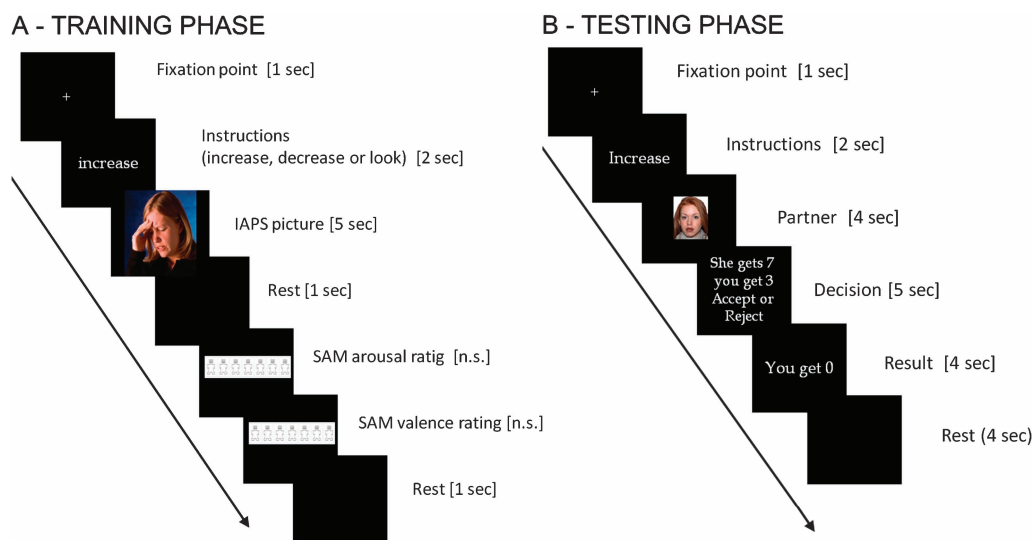


Figure 1. Experimental design, with Training phase (A) and Testing phase (B). In the training phase (outside the scanner) participants observed unpleasant IAPS pictures after receiving the relevant reappraisal strategy for that trial (increase, decrease, and look). After that, they rated on a two-scale Self Assessment Manikin the perceived arousal and valence. In the testing phase (inside the scanner) participants played the standard UG while applying the same reappraisal strategies.

respective strategies) and once in which they played without any reappraisal instruction (baseline condition). Based on van't Wout et al. (2010), the instructions given as to how to apply reappraisal strategies were as follows: "It is very important that you now apply the reappraisal strategies learned in the IAPS training to the situations evoked by the UG. In particular, you should try to come up with possible interpretations of the intentions and behaviors of the proposer in a way to make it more negative (up condition) or less negative (down condition). For example, when instructed to "increase," you could, for example, think that the other player is a selfish person (intentions) and wants to keep all the money (behavior). Whereas, when you have to "decrease," you could, for example, think that the player has financial problems and is making the best offer he/she can." In the "look" condition, participants were asked to read and respond to the offer spontaneously. Participants were debriefed following these 3 practice trials and asked to report their strategies for each trial. Once they had mastered the technique to the satisfaction of the experimenter, they were prepared for the scanning session. If they had not grasped these techniques, they were provided with further training and explanation. Notably, the focus of reappraisal was to be the "intentions and behaviors" of the player and not the economic offer itself.

After the UG training, participants entered the scanner and played a block of 20 trials for each of the 3 regulation conditions, counter-balanced across participants, for a total of 60 trials as responders. Each trial involved a division of 10 euros. Based on the results of a pilot study, strategy was blocked in order to avoid task-switching costs across strategies. The set of offers received by each participant was preassigned. This set of 20 offers per strategy was comprised of 7 fair offers (€5 to each player) and 13 unfair offers, defined as offering the participant less than half of the total amount. The unfair set was composed of 7 very unfair offers of €1 and of 6 mid-range values (2 offers of €2, 2 offers of €3, and 2 offers of €4). Half of the offers were made by a male partner and half by a female partner. The order of partners and the pictures associated with each offer was randomized.

On each trial, participants first saw a picture of the proposer on that round, followed by the offer of that player. After the offer was made, participants either accepted or rejected the offer. They then saw the associated outcome, that is, the payment to each player for that trial (see Fig. 1B for a timeline). To encourage participants to make real decisions, it was emphasized that they would be paid according to their choices in the game, in addition to a fixed amount for participation (though to comply with local ethical guidelines all were in fact paid the same amount).

Debriefing

In a postscan session, participants were shown 2 sample UG rounds used during the scanning session (specifically, a fair 5:5 offer and an unfair 1:9 offer) and were asked to evaluate the strength of emotions elicited (separately for anger, sadness, disgust, surprise, and happiness) on a 9-point Likert scale. After each example, they were also asked to indicate whether they felt their emotions were modulated according to the strategies used (up- and downregulation, respectively).

MRI Data Acquisition and Analysis

Stimulus presentation and data acquisition were controlled using E-prime software. Responses were made with the index and middle fingers of the right hand using 2 buttons on a 4-button MRI-compatible response box. Behavioral responses (IAPS ratings, rejection rates, and questionnaires) were analyzed using SPSS and STATISTICA. Whole brain distortion-corrected Echo Planar Images (EPI) with 32 axial slices (3 mm thick, 1 mm gap) were collected at 4T (Bruker MedSpec MRI), with a T_2^* -sensitive gradient echo spiral pulse sequence (time repetition of 2.2 s, time echo 33 ms, 75° flip angle, 64 × 64 data acquisition matrix). T_2 -weighted spin-echo scans were acquired for anatomical localization using the same slice prescription. Functional images were slice time corrected and motion corrected using SPM8 (Wellcome Department of Cognitive Neurology, London). For all participants, we acquired 738 volumes (246 for each fMRI run); the first 3 volumes were discarded for each run. In preprocessing of the data, the EPI volumes were spatially realigned to correct for movement artifacts (Ashburner and Friston

2003a) and motion corrected by distortion interaction (Andersson et al. 2001), transformed to the Montreal Neurological Institute standard space (Ashburner and Friston 2003b), and smoothed using 9-mm Gaussian kernel to account for residual intersubject differences and to accommodate assumptions of random field theory used for family-wise error corrections (Worsley and Friston 1995). All subsequent analyses of the functional images were performed using the general linear model implemented in SPM8. For statistical analysis, we modeled the onset of each category and convolved with the hemodynamic response function (event duration = 0), then estimated the effect size for each participant for each of the relevant 9 conditions (unfair rejected offer downregulate, unfair rejected offer look, unfair rejected offer upregulate, unfair accepted offer downregulate, unfair accepted offer look, unfair accepted offer upregulate, fair accepted offer downregulate, fair accepted offer look, and fair accepted offer upregulate) using the general linear model (Kiebel and Holmes 2003). Because our main question concerned the decisions taken in the UG, activation onsets were aligned with the display of the proposed monetary division on each trial. Finally, the first-level analyses included also the parameters of the realignment (motion correction) as covariates of no interest. Next, we obtained 9 parameter estimates per participants, corresponding to the 9 conditions of interest. Statistical threshold was set to P -corrected = 0.05 corrected for multiple comparisons (family wise corrected [FWE]) at the cluster level (peak size estimated at P -uncorrected = 0.001), using the whole brain as the volume of interest. Furthermore, region-of-interest (ROI) analyses were also carried out with the aim of providing additional information based on main effects and simple contrasts from the random effects analysis. Each ROI consisted of a sphere of 6 mm of diameter centered around the peak of activation using Marsbar toolbox (Brett et al. 2002).

Results

Behavioral Results

Training Phase, Debriefing, and Manipulation Check

We first examined if the affective ratings while reappraising IAPS pictures were different across conditions in the training phase. An analysis of variance (ANOVA), with type of measure (arousal vs. valence) and reappraisal strategies (down vs. look vs. up), returned a significant main effect of measure ($F_{1,20} = 73.707$, $P < 0.001$) as well as a significant interaction ($F_{2,40} = 26.978$, $P < 0.001$), but not the effect of reappraisal strategies ($F_{2,40} = 0.098$, $P = 0.909$). Next, we ran paired t -tests with participants' subjective ratings as dependent variables separately for both arousal and valence. All comparisons were significant, indicating that participants appeared to have learned reappraisal abilities—Valence: look versus down ($t_{1,20} = 6.30$, $P < 0.0001$), look versus up ($t_{1,20} = 2.52$, $P < 0.05$), and down versus up ($t_{1,20} = 5.9$, $P < 0.0001$); Arousal: look versus down ($t_{1,20} = -3.32$, $P < 0.005$), look versus up ($t_{1,20} = -2.22$, $P < 0.05$); down versus up ($t_{1,20} = -6.38$, $P < 0.0001$). When participants were required to downregulate, IAPS pictures were judged as less arousing and less unpleasant as compared with the look condition. When upregulating, the pictures were rated as more arousing and unpleasant (Fig. 2A). Importantly, to ensure that these ratings were comparable with the standard IAPS ratings, we computed a two-sample t -test between the ratings of the 6 pictures presented in the "look" baseline condition and the IAPS normative (United States) ratings of the same 6 pictures (Lang et al. 2008), with the 2 groups (participants vs. normative controls) as the grouping variable. We found no significant difference for both arousal ($t_{1,10} = 1.249$, $P = 0.240$) and valence ($t_{1,10} = 1.714$, $P = 0.117$). Then, to understand which emotion might be involved when reappraising the UG and to check for the success of our

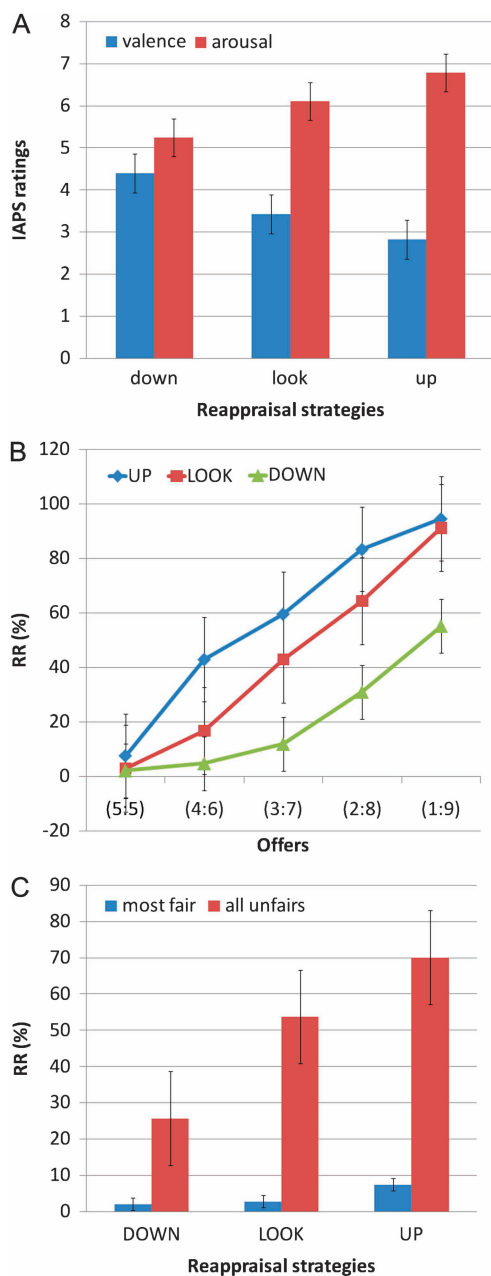


Figure 2. Behavioral data. In the Training phase (A), participants' perceived valence and arousal was significantly modulated by the reappraisal strategies adopted. A linear decrease (i.e., more negativity) for valence and the opposite trend for arousal were observed, showing that the perceived emotionality of the IAPS pictures was altered according to the modulation strategy. In the Testing phase (B), rejection rates (RR) interacted with strategy, with increased rejections in the Up condition for unfair offers, and increased acceptances in the Down condition for the same set of offers. Collapsing across unfair offers (from €1 to €4) (C) demonstrated a linear trend in the rejection pattern.

experimental manipulation, we analyzed the formal debriefing questionnaires that were completed after the experiment. This debriefing exposed subjects to the same kind of stimuli as was displayed during the scanning session, but added questions to understand the kind of emotion elicited, the level of emotional strength, and the perceived ability to modulate them when reappraising.

One participant was excluded due to noncompletion of the ratings. Paired *t*-tests were performed using subjective ratings

with all pairs of emotions as dependent variables. Results demonstrate that the level of anger significantly differed from all other emotions (anger-disgust: $t_{1,19} = 2.058$, $P < 0.05$; anger-surprise $t_{1,19} = 2.868$, $P < 0.01$; anger-happiness: $t_{1,19} = 6.064$, $P < 0.001$; anger-sadness: $t_{1,19} = 2.96$, $P < 0.05$); disgust differed from happiness ($t_{1,19} = 4.807$, $P < 0.001$) but not from surprise ($t_{1,19} = 1.539$, $P = 0.14$) and from sadness ($t_{1,19} = 0.847$, $P = 0.408$); surprise differed from happiness ($t_{1,19} = 4.578$, $P < 0.001$) but not from sadness ($t_{1,19} = -0.607$, $P = 0.55$); happiness differed from sadness ($t_{1,19} = -4.188$, $P < 0.001$). Overall, these results indicate that the emotion elicited by the unfair offers in postscan ratings was primarily anger, followed by other negative emotions, such as sadness and disgust. This may suggest that anger was the most likely emotion to be modulated by the reappraisal strategies when subjects reappraised the UG rounds in the scan session. Importantly, anger and disgust were stronger for unfair compared with fair offers (anger for 1€-anger for 5€: $t_{1,19} = 6.530$, $P < 0.001$; disgust for 1€-disgust for 5€: $t_{1,19} = 6.328$, $P < 0.001$). Finally, in a manipulation check, participants were asked to indicate whether they felt their emotions changed according to the strategy adopted. Results were computed as deviations from the mean (5 in a scale from 1 to 9) using paired *t*-tests with ratings for each of 2 offers as dependent variables. Participant ratings indicate that in the "Down" condition, both fair (5:5) and unfair (1:9) offers were modulated in the predicted direction ($t_{1,20} = 2.416$, $P < 0.05$ and $t_{1,20} = -3.141$, $P < 0.05$, respectively), while in the "Up" condition only the unfair offer was modulated in the expected direction ($t_{1,20} = 2.234$, $P < 0.05$; $t_{1,20} = 0.576$, $P > 0.05$) for the fair offer.

Rejection Rates in the UG

To examine the effect of reappraisal on acceptance rates, we conducted a 3 (emotion regulation strategies: down vs. look vs. up) \times 5 (offers: €5, €4, €3, €2, €1) within-subject ANOVA. Results showed a main effect of emotion regulation, $F_{2,28} = 18.9$, $P < 0.0001$, a main effect of offer, $F_{4,56} = 105.3$, $P < 0.0001$, and an interaction between emotion regulation and offer, $F_{8,112} = 17.2$, $P < 0.05$, all Greenhouse-Geisser corrected. Bonferroni-corrected post hoc tests demonstrated decreased punishment behavior (rejection rates) for most offers after downregulation, as compared with the look condition. In particular €1: difference = -36.05%, $P < 0.05$; €2: $d = -33.33\%$, $P < 0.05$; €3: $d = -30.95\%$, $P < 0.05$; €4: $d = -11.9\%$, $P > 0.05$; €5: $d = -0.68\%$, $P > 0.05$; and increased rejection rates after upregulation as compared with the look condition (€1: $d = 3.4\%$, $P > 0.05$; €2: $d = 19.04\%$, $P > 0.05$; €3: $d = 16.66\%$, $P > 0.105$; €4: $d = 26.19\%$, $P < 0.05$; €5: $d = 4.76\%$, $P > 0.05$). When comparing Up versus Down, all offers but one (€5) were significantly different ($P < 0.05$) (see Fig. 2B). Since, as expected, there was no effect of manipulation on the fair offers (€5), with almost all of these offers accepted, to maximize blood oxygen level-dependent signal, we collapsed across all the unfair offers (from €1 to €4) and compared these to the fair (€5) set. Additional Bonferroni-corrected analysis on these sets showed that for the fair offers, the strategies did not significantly affect the rejection rates (all P s > 0.05), whereas they strongly affected the unfair offer decisions ($P < 0.05$) (see Fig. 2C). Notably, there was a correlation between the change in the valence ratings (but not arousal) when reappraising the IAPS pictures, and the change in the rejection rates when reappraising the UG ($\rho = 0.493$, $P < 0.05$; $\rho = 0.14$, $P = 0.95$, respectively), both calculated as the difference between Up

and Down conditions (as a measure of reappraisal success), showing that participants good at reappraising emotional pictures were also good at reappraising decisions.

Imaging Results

To begin with, an initial set of contrasts was examined to explore the effects of reappraisal strategy ("Effect of strategy"). This included the main effect of strategy, independent of offer amount and decision, as well as additional analyses to examine the effect of each of the 3 strategies (Up, Down, and Look) on each offer type (fair accepted, unfair accepted, and unfair rejected)—as expected, virtually no fair offers were rejected). This resulted in 9 separate contrasts (fair accepted during downregulation, fair accepted during look, fair accepted during upregulation, unfair accepted during downregulation, unfair accepted during look, unfair accepted during upregulation, unfair rejected during downregulation, unfair rejected during look, unfair rejected during upregulation).

Next, we computed 2 sets of contrasts to identify regions associated with regulated versus unregulated decisions ("Effects of regulated vs. unregulated decisions"). The first contrast looked at a greater number of accepted offers during downregulation and a greater number of rejected offers during upregulation. The second answered a similar question, but looked at unfair accepted > unfair rejected during downregulation, and unfair accepted < unfair rejected during upregulation.

Finally, to identify regions that were modulated according to the strategies employed, we computed the contrast down < look < up (e.g., isomorphic with the behavioral pattern as shown in Fig. 2C), for each of the 3 sets of trial types, resulting in 3 contrasts (down < look < up for fair accepted, down < look < up for unfair accepted, down < look < up for unfair rejected) ("Effects of regulation").

Effects of Strategy

Regions involved in the implementation of reappraisal strategies (collapsing across offer type) are shown in Table 1A and Figure 3. Active brain regions, in order of significance, were bilateral precuneus, the left inferior, middle, and superior frontal gyrus (SFG) (collectively DLPFC), and bilateral anterior cingulate cortex (ACC). Overall these regions responded more strongly to both the "Down" and "Up" conditions as compared

with the "Look" condition. In addition to the general effects outlined above, we were also interested in how the different strategies (up vs. down) were implemented for the different offer types. In these analyses, we looked at responsiveness to strategy separately for unfair rejected (see Table 1B), unfair accepted and fair accepted offers.

For the unfair rejected offers, the analyses produced similar activations to the main effect of strategy, with significant activation of the right DLPFC (middle/inferior frontal gyrus [M/IFG], Brodmann area [BA] 9), Anterior Cingulate (BA 32), and SFG (BA 6). The same contrast for unfair accepted and fair accepted offers did not return any significant activation. We focused on the activity of IFG, a region previously associated with reappraisal (Ochsner et al. 2002; Ochsner and Gross 2005) (see Fig. 3). Activation time courses were extracted using Marsbar toolbox (Brett et al. 2002) from a 6 mm sphere centered around the peak of activity. Stronger responses were evident for unfair rejected offers for the 2 regulation strategies as compared with the baseline look condition. Moreover, stronger activity was observed for the Up as compared with the Down strategy. In contrast, the unfair accepted and the fair accepted offers were, as expected, not modulated by the strategy in line with the primary contrasts for the same conditions.

To determine whether activation in IFG during UG regulation might be related to individuals' self-reported use of emotion regulation, we correlated individuals' IFG mean activity with their ERQ (reappraisal subscale) scores (Gross and John 2003). This demonstrated a significant positive correlation ($\rho = 0.653$, $P < 0.001$), indicating that the reported frequency of reappraisal usage in daily life (i.e., a higher score in the ERQ-reappraisal subscale) was associated with stronger IFG activity during emotion regulation on UG trials. This confirms and extends a role for the DLPFC in reappraisal (Drabant et al. 2009) (see Fig. 4A, right).

Effects of Regulated Decisions

In addition to the general effect of applying a reappraisal strategy, we were also interested in looking at neural activation when participants regulated their decision (for each of the 2 strategies) as compared with when they did not. We defined downregulated decisions as an increased number of unfair offer acceptances. Regions responding to downregulation, calculated as greater activity for unfair accepted offers in the "Down" as compared with "Look" condition, were the left middle frontal gyrus (MFG), as well as the left superior temporoparietal regions, bilateral SFG, and the anterior cingulate. Of these regions, the SFG also correlated with acceptance rates of subjects ($\rho = 0.399$, $P < 0.05$; see Table 2A and Fig. 4A). Conversely, regions associated with upregulated decisions, that is, greater activity for unfair rejected offers in the "Up" compared with "Look" condition, were the left IFG as well as the insula bilaterally, and the right MFG and left SFG, and a swathe of temporoparietal regions. Of these regions, the right MFG correlated with rejections rates of the subjects ($\rho = 0.416$, $P < 0.05$; see Table 2B and Fig. 4B). The question of which brain regions are responsible for regulated decisions can also be answered by computing the contrast "unfair accepted > unfair rejected for downregulation," and "unfair accepted < unfair rejected for upregulation." These contrasts, interestingly, confirmed the results found by the previous contrasts (SFG/

Table 1
Effects of strategy; (A) main effect of strategy (Down + Up > Look) and (B) effect of strategy for unfair rejected (Down + Up > Look)

Anatomical label (BA)	Voxel	H	Z	P	MNI (x, y, z)
(A)					
Precuneus (7)	291	L	4.72	<0.001	-3, -55, 64
IFG (44)	71	L	4.60	<0.001	-51, 5, 13
AC (24)	62	L	4.54	<0.001	-3, 29, 7
MFG (9)	40	L	4.46	<0.001	-30, 35, 34
SFG (10)*	126	R	3.94	<0.001	15, 5, 70
MFG (6)*	21	R	3.47	<0.001	45, 2, 46
(B)					
IFG-MFG (9)	93	R	4.89	<0.001	39, 11, 22
AC (32)	48	L	4.53	<0.001	-9, 32, 13
SFG (6)*	17	L	3.16	0.001	-27, 32, 58

Note: Clusters of more than 10 contiguous voxels, whose global maxima at the cluster level meet a $P < 0.05$ FWE, (noted with *) or $P < 0.001$ uncorrected are reported. H, hemisphere; IPL, intraparietal lobule; CG, cingulate gyrus; OC, occipital cortex; MeFG, medial frontal gyrus.

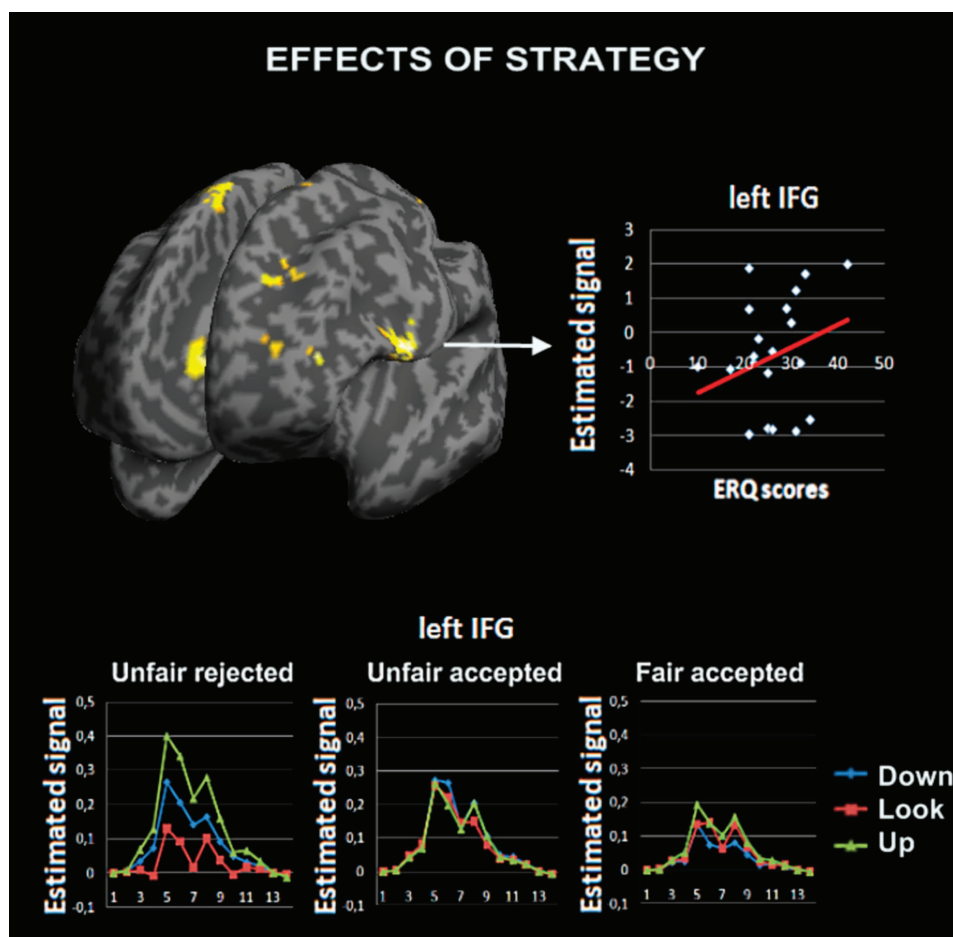


Figure 3. The main effect of strategy returned significant activations for left IFG, MFG, right SFG, and bilateral anterior cingulate (AC). Overall these regions responded more to Up and Down conditions as compared to Look, independent of offers and the decision (accept/reject). Of these regions the IFG BOLD activity showed selective activations for Up and Down compared with Look only for unfair rejected offers. Moreover, IFG correlated with the Emotion Regulation questionnaire measure, suggesting a role for this region when regulating emotions more generally.

MFG for downregulation and IFG/MFG, insula, and temporoparietal regions for upregulation).

Effects of Regulation

Finally, we were interested in examining brain regions modulated by the reappraisal strategies. Active regions modulated by reappraisal, that is, mimicking the behavioral effect (Down < Look < Up), were found only for unfair rejected offers and consisted of the posterior and anterior left insula, the posterior cingulate cortex, the medial frontal gyrus, bilateral fusiform gyrus, and the inferior parietal lobe (see Table 3). The same contrast applied to both unfair accepted and fair accepted offers respectively did not return any significant voxels. To further characterize the activity of the anterior and posterior insula, a region shown previously to be involved in UG decisions, activation time courses extracted from the voxels were computed. Up and Down modulation was evident in the posterior insula, showing greater activation for Up as compared with Look and greater for Look as compared with Down. Anterior insula showed a modulation only for Up (see Fig. 5).

Discussion

The aim of the present study was to examine the extent to which decision making in a socially interactive context could

be modulated by using emotion regulation strategies, specifically reappraisal. Although it seems evident that emotional factors play a role in these decision situations, it is still largely unknown how these processes operate. In particular, we were interested in the neural mechanisms by which emotion regulation strategies changed participants' responses to unfair UG offers. We found that decisions were altered according to the specific strategy used and additionally that these decisions were associated with specific patterns of neural activity.

The Reappraising Brain and Mentalizing

The specific reframing strategies utilized here affected several brain regions. Use of both up- and downregulation strategies recruited the DLPFC, including the inferior, middle, and SFG, as well as the ACC, and temporoparietal areas. Activity in these regions is in accordance with previous findings on regulating emotions induced by simple visual stimuli (Ochsner et al. 2004; Goldin et al. 2008), thus extending the role of these areas into the regulation of more complex socioeconomic emotions.

Overall, the regions involved in both regulation strategies can be grouped into several functional clusters. The DLPFC has been implicated in active cognitive control and inhibition (Knight et al. 1999; Smith and Jonides 1999; Miller and Cohen 2001), and may underlie the generation and

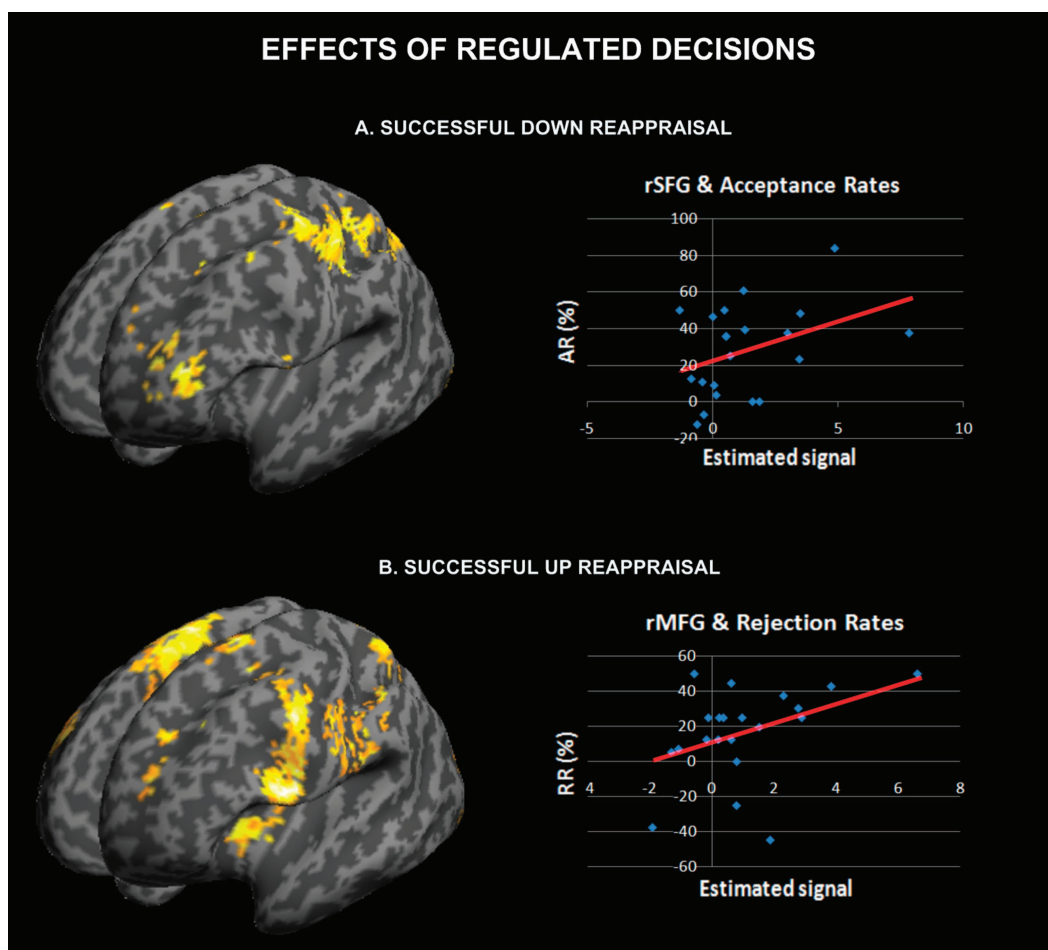


Figure 4. Brain regions involved in regulated decisions. Downregulated decisions (A) were calculated as the regions more active for unfair accepted offers, and returned predominantly the left superior and MFG. Upregulated decisions (B) were calculated as the regions more active for unfair rejected offers, and returned primarily the left IFG.

Table 2

Effects of regulated decisions; (A) down reappraisal (unfair accepted Down > Look) and (B) up reappraisal (unfair rejected Up > Look)

Anatomical label (BA)	Voxel	H	Z	P	MNI (x, y, z)
(A)					
PL (2)	642	L	4.79	<0.001	-36, -19, 70
MFG (10)	121	L	4.63	<0.001	-36, 41, 7
ACC (32)	46	L	4.11	<0.001	-18, 32, 22
Precuneus (7)	307	L	4.08	<0.001	-6, -55, 64
SFG (6)	58	L/R	3.78	<0.001	6, 8, 67
(B)					
IFG (9)	779	L	5.15	<0.001	-48, 2, 19
Insula (13) ^	31	L	4.92	<0.001	-45, 5, 10
MFG (10)	1647	R	4.87	<0.001	45, -1, 40
Insula (13) ^	31	R	4.45	<0.001	36, 17, 4
SFG (9)	49	L	4.53	<0.001	-30, 35, 34
PL (7)	97	L	4.42	<0.001	-27, -61, 55
SFG (9)	59	R	4.19	<0.001	24, 44, 28
OC (18)	200	R	4.07	<0.001	15, -70, -5
IPL (40)*	38	L	4.03	<0.001	-54, -37, 49

Note: Clusters of more than 20 contiguous voxels whose global maxima at the cluster level meet a $P < 0.05$ FWE, or $P < 0.001$ uncorrected (as noted with *), are reported. ^ indicates regions included in the main clusters, separated with small volume corrections. H, hemisphere; a.Insula, anterior insula; p.Insula, posterior insula; PL, parietal lobe; IPL, intraparietal lobule; OC, occipital cortex; MeFG, medial frontal gyrus.

Table 3

Effects of regulation (unfair rejected offers for Down < Look < Up)

Anatomical label (BA)	Voxel	H	Z	P	MNI (x, y, z)
IPL (40)	204	R	6.86	<0.001	33, -37, 40
FG (18)	597	L	6.55	<0.001	-27, -88, 7
FG (18)	516	R	6.42	<0.001	33, -88, -14
p.Insula (13)	22	L	6.28	<0.001	-45, -22, 25
IFG (9)	43	R	6.14	<0.001	39, -1, 34
MeFG	366	L	5.98	<0.001	-24, -4, 43
CG (6)	138	R	5.97	<0.001	-3, -7, 58
Insula	28	R	5.87	<0.001	27, 20, 7
MeFG	26	L	5.68	<0.001	-51, 2, 7
Precuneus	26	L	5.64	<0.001	-21, -70, 40
a.Insula	7	L	5.49	<0.001	-36, 11, 4

Note: Clusters of more than 6 contiguous voxels whose global maxima at the cluster level meet a $P < 0.05$ FWE, are reported. ^ indicates regions included in the main clusters, separated with small volume corrections. H, hemisphere; a.Insula, anterior insula; p.Insula, posterior insula; IPL, intraparietal lobule; CG, cingulate gyrus; OC, occipital cortex; MeFG, medial frontal gyrus.

maintenance of reappraisal strategies (Ochsner et al. 2002, 2004). The ACC has been shown to play an important role in the online monitoring of performance and evaluating the need

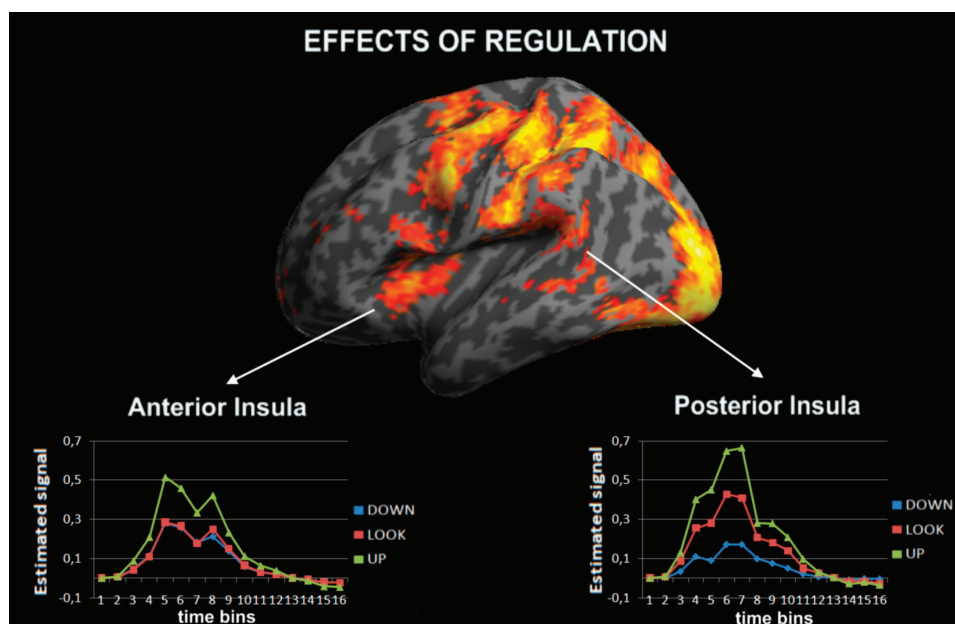


Figure 5. Regions modulated by reappraisal in line with the behavioral pattern (i.e., down < look < up, Fig. 2C), returned regions showing a linear increase only for unfair rejected offers. Anterior and posterior subregions of the left insula showed differential patterns, with the posterior part being more affected by the strategy. For display purposes, the brain reported in this figure has been thresholded at $P < 0.001$ uncorrected (instead of $P < 0.05$ FWE as reported in the tables).

for cognitive control in case of conflicting responses or motives (Botvinick et al. 2001; Ochsner et al. 2004; Yeung and Sanfey 2004). Importantly, the ventral part of the prefrontal cortex is well connected with brain structures such as the insula, which have been implicated in the affective response to unfair offers (Sanfey et al. 2003). One hypothesis derived from these activations is that the prefrontal cortex actively modulates insular activity via reappraisal in order to produce a decision more consistent with the regulation context.

The medial prefrontal cortex, including the paracingulate cortex and also temporoparietal areas, have been implicated in mentalizing and intention detection (Frith U and Frith CD 2003), and may be particularly important here, as reappraisal strategies specifically led participants to reinterpret the intentions of their opponents, as assessed by self-report measurements taken after scanning. Making sense of social interactions requires inferring intentions, beliefs, and desires (i.e., mentalizing; see Frith et al. 1991), and this appears to be what players were doing when applying the reappraisal strategies during the UG. This is in concurrence with a recent study that demonstrated mentalizing abilities at work when making value-based decisions (Evans et al. 2011).

Interestingly, this activation pattern has been previously reported both when reappraising emotional pictures (Ochsner et al. 2004) and obtaining rewards in monetary games (Staudinger et al. 2009; Martin and Delgado 2011). One interpretation might therefore be that DLPFC is involved in modulating both behavioral and emotional outputs in order to satisfy contextual demands (Mitchell 2011).

Decision Making Can Be Influenced in Different Directions

Our data demonstrate that reappraising the context of socioeconomic exchanges strongly affected players' behavior,

as well as the associated neural activity. Participants were trained in the use of up- and downregulation strategies, which provide a means to influence emotional reactivity by manipulating the cognitive interpretation of a stimulus and consequently changing the emotional response (Gross 2002). Previous studies (Gross and John 2003; Sokol-Hessner et al. 2009; Staudinger et al. 2009; Jarcho et al. 2011; Martin and Delgado 2011) have shown that this strategy modulates emotional reactivity. Here, we demonstrated that rejection rates in the UG were affected by the strategy adopted: participants accepted significantly more unfair offers when downregulating and rejected significantly more unfair offers when upregulating, as compared with a control condition in which regulation was not used. Notably, these effects were within subject, that is, individuals altered their decisions, and therefore presumably their sensitivity to fairness concerns, depending on the context. This is important, as typically participants in the UG exhibit quite consistent patterns, and therefore a demonstration of regulation effects within subject makes a strong case for the power of the reappraisal effect.

Recent experiments have demonstrated changes in decision making following both incidental emotional induction (Harlè and Sanfey 2007; Moretti and di Pellegrino 2010; Bonini et al. 2011), and neurophysiological manipulation via Transcranial Magnetic Stimulation (van't Wout et al. 2010; Knoch et al. 2006), but this study extends these findings in important ways by demonstrating that emotions directly related to the offer itself can be controlled through top-down effort, leading to changes in decisions and associated outcomes.

The present study also extends previous results (van't Wout et al. 2010), in which participants were instructed to use the down-regulation strategies of both reappraisal and suppression. This study found effects of downreappraisal only, but utilized a between-subjects design and did not address potential neural mediators of this process, nor the effect of upregulation. Here, we use both up- and down-reappraisal strategies and a within-

subjects design, and additionally provide neural evidence of successful regulation in decision making. Moreover, the present study extends previous results on emotional regulation more generally by demonstrating that reappraisal can significantly modify interpersonal socially driven emotions, as opposed to simple negative emotional responses to unpleasant pictures (Ochsner et al. 2004), or emotions associated with individual decision making (Sokol-Hessner et al. 2009; Staudinger et al. 2009; Martin and Delgado 2011).

Regulation and the Insula

Of particular interest in the context of the UG was the activity observed within the insula, an area previously shown to be involved in responses to offers (Sanfey et al. 2003), in particular to rejections of unfair offers. Consistent with previous studies (Pillutla and Murnighan 1996; Fehr and Gächter 2002; Camerer 2003; Xiao and Houser 2005), postscanning debriefing demonstrated that anger was the primary emotion elicited by the unfair proposals. Interestingly, neural evidence of the involvement of the insula in the emotion of anger has been recently shown (Denson et al. 2009). This area showed functional specificity in the present study—activity in more anterior areas was affected by upregulation but not by downregulation, with a more posterior region strongly affected by both regulation strategies, and in which activity tracked closely with the behavioral findings. The 2 subregions of the insula active in our study (anterior and posterior) overlap with recent functional-cytoarchitectural subdivisions suggested by animal and human studies (Wager and Barret 2004). According to this classification, the anterior agranular insula processes drive and emotional states such as body feelings and motivations (Freeman and Watts 1950). In contrast, the more posterior subregion of the insula may be more strongly connected to somatic and visceral inputs and outputs, assisting the interpretation and modulation of the autonomic signals ascending from the body. This model overlaps with one proposed by Craig (2009), which posits that the anterior insula processes social motivational and cognitive conditions as well as hedonic evaluations, whereas the posterior part processes visceral interoceptive representations. Therefore, this suggests that the posterior part of the insula, via its known connections to the perception of autonomic and visceral states, is a mechanism by which the reappraisal strategies could affect the emotional perception of the offers.

Interestingly, several other regions were affected by regulation in a down < look < up fashion. For example, visual cortices and fusiform areas showed a modulation, likely due to their role in perceiving the face of the proposer. This suggests that participants may have already started their interpretation of the proposers' behavior at the time the identity of the player is uncovered. Another region modulated was a section of parietal cortex. One possible explanation for this activation is that participants may have altered their perception of the monetary offers according to the strategy (e.g., interpreting a low offer as even lower because of an upregulation strategy). Finally, the posterior-medial cingulate cortex was also modulated. This region has been previously associated with negative emotions, especially anger (Murphy et al. 2003), which is the specific emotion that appeared to be involved here when regulating. Though these are certainly speculative interpretations, future

studies could usefully test these hypotheses and build a broader picture of brain regions modulated by reappraisal.

Implications for the Role of Dorsolateral Prefrontal Cortex in Decision Making

Our data demonstrate multiple roles for the dorsal and ventrolateral prefrontal cortex in emotional regulation and decision making. First, this region (mainly BA 44, 46, and 9), together with other areas, was involved in the implementation of the 2 reappraisal strategies. Second, activity in this region correlated with ratings on the ERQ (Gross and John 2003), implicating DLPFC in the frequency with which we apply regulation strategies. There are well-established individual differences in terms of the ability to regulate emotions (Gross and John 2003; Drabant et al. 2009), and DLPFC functionality may be responsible for this variability. This is consistent with a proposed model regarding the role of prefrontal cortex in modulating emotions (Ochsner and Gross 2005; Drabant et al. 2009). Third, we provided evidence that DLPFC activity correlates with acceptance and rejection rates in the successful “Down” (more lateral) and “Up” (more ventral) regulation conditions, showing a further segregation of this region in line with recent results (Wager et al. 2009). This region may play a key role in modulating the impact of emotional stimuli providing a flexible contribution to modulate our decisions. The involvement of this region in both decision making and regulation is interesting, and may reflect the fact that both of these processes are influenced by emotion (Mitchell et al. 2011).

Although previous studies have implicated DLPFC in the UG behavior (e.g., Sanfey et al. 2003), asking participants here to reappraise the proposer's offer (and behavior) amplified the process of evaluation. The fact that DLPFC increases in activity when implementing strategies further clarifies the role of this region in decision making, which may well be to process the multiple motives, from personal norms to objective evaluations to emotional reactions, necessary to produce a context appropriate decision. An important reason why we should consider decision making and emotion regulation together is that coexisting abnormalities in these processes are associated with aberrant social behavior in many psychiatric disorders (Mitchell 2011).

In conclusion, we provide evidence here, both behaviorally and neurally, that the typical decision pattern that accompanies an unfair Ultimatum offer can be changed following reappraisal of the proposer behavior, and suggest neural mechanisms by which this process may occur.

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