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A negative emotional and economic judgment bias in major depression

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Abstract Although major depression is projected to be among the top three causes of disability-adjusted life years lost in 2030, relatively little is known concerning the extent to which depressed mood states can bias social–economic decision making away from optimal outcomes. One experimental framework to study the interaction between negative emotion and social–economic decisions is the ultimatum game (UG), where the fair, cooperative player altruistically punishes the unfair, non-cooperative player. To assess a potential susceptibility of altruistic punishment to depressed mood, we repeatedly administered the UG task to a cohort of 20 currently depressed patients with a diagnosis of recurrent major depressive disorder and 20 healthy controls. Furthermore, valence and arousal ratings of emotionally laden pictures were obtained from all participants in order to assess a depressed mood-related distortion of emotion judgments. Compared to healthy controls, depressed patients over-sanctioned unfair proposals in the UG and judged emotional stimuli too negatively. Thus, major depression is associated with a negative emotional bias that hampers social–economic decision making and produces large personal costs.

Keywords Altruistic punishment · Decision making · Emotion · Neuroeconomics · Major depression · Ultimatum game

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Introduction

A hallmark of human bargaining is the inclination to sanction unfair, non-cooperative behavior. This punishment of social norm violations is often altruistic [1], occurs panculturally across human societies [2], and may result from an evolutionary strategy that supports cooperation [3]. One experimental framework to study altruistic punishment is the ultimatum game (UG), a two-person one-shot exchange game, in which one player, the proposer, can make an offer and the other player, the responder, can either accept or reject this offer [4]. Altruistic punishment is reflected by the fact that individuals tend to reject low, unfair offers, although this is costly for them by yielding no material gain [5].

Despite substantial evidence indicating that the responder behavior in the UG is proximately motivated by a negative emotional response to perceived unfairness, surprisingly few studies have so far examined the susceptibility of altruistic punishment to depressed mood. Major depressive disorder (MDD) affects up to 20 % of the worldwide population [6, 7] and is associated with a negative cognitive bias toward pessimistic judgments [8]. Ecologically valid social–economic tasks such as the UG may thus help to better characterize the behavioral deficits associated with MDD [9–11].

Based on the existing studies, no consensus has evolved on whether depressed mood alters altruistic punishment [12] or not [13], despite mounting evidence that experimental inductions of sadness [14] and disgust [15] (see also [16]) modulate the rejection rate and that UG behavior and risky decision making are biased in individuals with schizophrenia [17–19] (but see [20]) and psychopathy [21]. The autonomic arousal component of emotional reactions to unfair offers is reflected by changes in electrocardiac

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[22] and electrodermal activity [23]. In addition, unfair offers are characterized by a specific neuroelectric signature involving a larger medial frontal negativity (MFN) component [24, 25]. The neural network underlying altruistic punishment has been shown to involve the anterior insular cortex (AIC) [26] and the amygdala [27, 28] in addition to striatal reward centers [29], that is, brain regions that have also been meta-analytically confirmed as being structurally and/or functionally altered in MDD [30, 31]. AIC activity correlates with the decision to accept or reject unfair proposals [26] and is modulated by instructed emotion regulation [32]. Single-dose administration of a benzodiazepine not only reduces the rejection rate of unfair offers but also diminishes amygdala responses in healthy volunteers [27]; similarly, two rare patients with focal bilateral amygdala lesion display a profoundly altered rejection profile in the UG [28]. Furthermore, experimental variation in serotonergic (serotonin, 5-HT) tone can either increase or decrease altruistic punishment, as shown by tryptophan depletion [33] and administration of the selective 5-HT reuptake inhibitor (SSRI) citalopram [34].

Against this empirical background, we recruited a clinical cohort of 20 currently depressed patients with a diagnosis of recurrent MDD and compared their performance on valence and arousal judgments of emotional stimuli (task 1) and their rejection profile in the UG (task 2) to 20 healthy controls (HC). We hypothesized that MDD patients would exhibit a profound negative emotional bias associated with higher-than-normal rejection rates in the UG.

Methods

Subjects

Conducted in accordance with the latest revision of the Declaration of Helsinki, the study was approved by the institutional review board (IRB) of the University of Bonn Medical Faculty. All volunteers approved participation by signing an informed consent. The study included 20 HC and a clinical cohort of 20 depressed inpatients meeting DSM-IV [35] diagnostic criteria for recurrent MDD. All patients received antidepressant medication (SSRIs, SNRIs, NaSSAs, or tricyclic antidepressants), with nine patients additionally taking atypical antipsychotics and one patient receiving lithium carbonate for augmentation purposes. MDD patients reported a mean number of 3.67 past episodes and a mean duration of 14.67 weeks for the current episode. On average, baseline assessment was conducted 15 days after the patients were admitted (session 1). The follow-up was carried out, on average, 40 days later (session 2). In the HC sample, the time interval between session 1 and session 2 was, on average, 43 days. HC were recruited by advertisement from the local community, had no history of neurological or psychiatric disorders, and were currently free of DSM-IV axis I or II disorders.

Clinical and neuropsychological measures

We employed two behavioral measures of depression severity, the Hamilton Depression Rating Scale (HAMD, 17 items) [36] and the self-rating Beck Depression Inventory (BDI-II) [37]. Trait anxiety and impulsivity were measured with the State/Trait Anxiety Inventory (STAI) [38] and the Barrat Impulsiveness Scale (BIS-11) [39]. Neuropsychological testing in the first and second sessions included the DST (digit-span test), derived from the revised Wechsler adult intelligence scale (WAIS-R) [40] to assess working memory performance, the MWT-B ('Mehrfach-Wortschatz-Intelligenztest Teil B') [41] to assess verbal IQ based on lexical decisions, the 'd2' test of attention ('Aufmerksamkeits- und Belastungstest d2') [42] to assess visual attention and concentration, and the trail-making test (TMT) [43] part A and B to assess visual attention and task-switching performance.

Ultimatum game task

A cover story was invented to convey the impression that all subjects played with real human beings. Participants were led to believe that the study was conducted in cooperation with another research group and that they had to interact with persons tested in the other laboratory. It was emphasized that there would be no repeated interactions, such that they would encounter every player only once ('one-shot' trials). Moreover, they were told they would be randomly assigned to either the proposer or responder group. In fact, all participants played the game as responders. Furthermore, they were instructed that one of the trials would be randomly selected to determine how much they would be paid at the end of the experiment. In each test session there were 54 trials in total, each with a different proposer. Half of the proposers were female and half male. The order of offers and the assignment of proposers to these offers were randomized. Each trial started with the presentation of a fixation cross for a random time interval of between 3 and 4 s. Then a picture of the proposer was displayed for 1 s, after which the proposer's offer was presented for 10 s. Subjects could accept or reject an offer by pressing one of two response buttons. They were instructed to make their decisions as quickly as possible. Importantly, we varied the amount offered across trials. The UG consisted of twelve different allocations of 10 €, such that the participant was proposed 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, or 5.5 €. Each proposal was repeated five times, with the exception of 0 and 5.5 €

which were presented only twice. The UG paradigm was implemented in Presentation 14 (Neurobehavioral Systems, Albany, CA). After completing the task, in the second session subjects were debriefed and asked whether they had any suspicions concerning the cover story. In addition, all subjects were asked to threshold the smallest amount of money they regarded as acceptable. Furthermore, they were instructed to rate the fairness of all offers on a scale of 1 (minimum)–7 (maximum) and to make one offer as proposer.

Emotion judgment task

Emotional judgment behavior was studied by presenting pictorial items selected from the International Affective Picture System (IAPS) [44] as previously described [28]. Specifically, participants were instructed to rate their emotional impact on the dimensions of valence and arousal. This two-dimensional view of emotion was first formalized by Wundt [45] and has received substantial empirical support ever since. Mehrabian and Russel [46] showed that most of the variance in descriptions of emotions can be explained by the factors valence and arousal. This is reflected in the IAPS which was constructed to cover the whole emotional spectrum (affective space) on both dimensions [44]. Subjects were administered two sets of IAPS pictures and the self-assessment manikin (SAM) in order to report valence and arousal for each item on a scale of 1 (minimum)–9 (maximum). The administration of the picture sets was balanced across the two sessions. Each set contained 90 pictures, of which one-third was valenced either negatively, neutrally, or positively according to the normative IAPS ratings. The picture content comprised attractive women (for male participants) and men (for female participants) and erotic couples in the pleasant condition, daily living situations as well as waiting and working humans in the neutral condition, and mutilated bodies as well as fighting and injured humans in the negative condition. All items were displayed in a random order.

Statistical analysis

Demographical, neuropsychological, and psychophysiological data were analyzed using SPSS 19 (SPSS Inc., Chicago, IL, USA). Quantitative behavioral data were compared by repeated measures analyses of variances (ANOVA). For continuous and categorical variables, partial eta-squared (parametric) and r coefficients (non-parametric) and phi were calculated as measures of effect size, respectively. The assumption of sphericity was assessed with Mauchly's test, and the Greenhouse–Geisser's correction was applied for significant violations. For qualitative variables, Pearson's chi-squared tests were used. The association between two quantitative variables was analyzed by Pearson's correlations. All reported p values are two-tailed or one-tailed if a priori hypotheses regarding the direction of effects were established. Values of $p < 0.05$ were considered significant. Squared Euclidian distances (SED) were calculated separately for each valence category as composite scores of the emotional bias involving both valence and arousal judgments. The individual valence score difference, the mean valence value of the control group, the individual arousal score difference, and the mean arousal value of the control group were computed, squared, and summed. The sum of the squared differences represents the SED score of a participant.

Results

Demographic, neuropsychological, and clinical profiles

MDD patients and controls did not differ regarding gender distribution, age, body indices, years of education, and premorbid IQ, whereas trait anxiety and impulsivity levels were significantly elevated in MDD patients (Table 1). MDD patients also showed significantly larger BDI-II and HAMD scores (Table 2). At follow-up, eight patients (40 %) had responded to treatment, evident in a ≥50 % reduction in baseline depression scores. Overall, the depression severity was significantly decreased across all patients (BDI: −25.7 %; $t_{(18)} = 3.21$, $p < 0.01$, $r = 0.60$; HAMD: −37.7 %; $t_{(18)} = 3.97$, $p < 0.01$, $r = 0.68$). Similarly, visual attention and concentration indices as assessed with the d2 test improved after treatment ($t_{(17)} = -2.29$, $p = 0.04$, $r = 0.49$).

Ultimatum game task

A repeated measures ANOVA with 'offer size' (0–5.50 €) and 'treatment' (baseline and follow-up) as within-subject factors, 'group' (MDD patients and controls) as the between-subject factor, and the rejection rate as the dependent variable yielded a significant main effect of 'offer size' ($F_{(4.05,\ 153.95)} = 98.18$, $p < 0.01$, $\eta^2 = 0.72$). Thus, lower offers were more often rejected than higher ones by both patients and controls, a finding consistent with the previous studies in non-patient samples. There was also an interaction effect of 'offer size' and 'group' ($F_{(4.05,\ 153.95)} = 3.24$, $p = 0.01$, $\eta^2 = 0.08$) and a significant squared planned contrast ($F_{(1,\ 38)} = 9.25$, $p < 0.01$, $\eta^2 = 0.20$), indicating that MDD patients rejected slightly unfair offers more often than controls (Fig. 1). Importantly, there was neither a main nor an interaction effect of 'treatment' (all p's > 0.23),

Table 1 Demographics and personality traits

	MDD group ($n = 20$) Mean (±SD)	HC group ($n = 20$) Mean (±SD)	χ^2/t	p	*Phi/r*
Female sex	16	12	1.91	0.17	0.22
Age (years)	47.75 (12.61)	41.10 (14.40)	−1.55	0.13	0.24
Height (cm)	166.60 (8.31)	168.70 (11.74)	0.65	0.52	0.11
Weight (kg)	80.14 (19.99)	76.23 (17.73)	−0.65	0.52	0.11
Years of education	16.08 (3.52)	17.71 (3.87)	1.19	0.25	0.22
MWT-A[a]	29.32 (3.83)	29.75 (3.35)	−0.38	0.71	0.06
STAI trait[b]	51.90 (7.28)	42.35 (3.69)	−5.24	<0.01	0.70
Global impulsivity[c]	72.00 (7.50)	62.50 (11.97)	−3.01	<0.01	0.47
Motor impulsivity[c]	28.75 (3.45)	25.00 (5.28)	−2.66	0.01	0.42
Cognitive impulsivity[c]	43.25 (5.21)	37.50 (7.32)	−2.86	<0.01	0.42

Premorbid IQ based on lexical decisions was assessed by the [a] MWT-A (Mehrfachwahl-Wortschatz-Intelligenz-Test Teil A) (maximum possible score 37). Trait anxiety and impulsivity were assessed with the [b] *STAI* State Trait Anxiety Inventory and the [c] Barrat Impulsiveness Scale. For categorical and continuous variables, phi and r coefficients were calculated as measures of effect size, respectively. *MDD* major depressive disorder, *HC* healthy controls

showing that the improvement in depression scores after therapy did not affect UG decisions. In accordance with this notion, an exploratory analysis of the UG behavior at follow-up revealed no significant difference (all p's > 0.24) between treatment responders and non-responders. The observed behavioral differences between patients and controls cannot be attributed to a deviant fairness perception of the patients since a repeated measures ANOVA, with the fairness ratings as dependent variables, only revealed a significant main effect of 'offer size' ($F_{(5.50,\ 209.04)} = 268.73$, $p < 0.01$, $\eta^2 = 0.88$) but neither a main nor an interaction effect of 'group' (all p's > 0.26; Fig. 1). Thus, we found a linear relationship between the proposed share and fairness rating for shares from 0 to 5 €, that is, larger offers were generally considered to be more fair by both patients and controls. Furthermore, it is also unlikely that cognitive deficits in the patients contributed to the observed discrepancies in UG decisions, since there were no interaction effects of 'group' and 'offer size' or 'treatment' in a repeated measures ANOVA with reaction time (RT) as the dependent variable (all p's > 0.09). Interestingly, patients and controls were comparable ($p = 0.68$) in the amount of money both groups regarded as just acceptable, which reflects a dissociation of their cognitive evaluation and their actual responder behavior in the UG. In contrast, patients significantly differed from controls in the amount of money they would offer as proposers ($t(35) = -2.19$, $p = 0.04$, $r = 0.35$), that is, patients ($M = 5.29$, SD = 1.25) were willing to offer a

Table 2 Clinical profile and neuropsychological performance at baseline and follow-up

	MDD group ($n = 20$) Mean (±SD)	HC group ($n = 20$) Mean (±SD)	t	p	r
Baseline					
BDI[a]	32.30 (9.66)	4.25 (3.54)	−12.19	<0.01	0.93
HAMD[b]	21.70 (6.68)	1.15 (1.39)	−13.67	<0.01	0.95
d2[c]	108.89 (40.45)	154.20 (64.99)	−2.63	0.01	0.42
TMT-A[d] (seconds)	41.74 (23.34)	36.20 (20.22)	0.79	0.43	0.12
TMT-B[d] (seconds)	94.42 (28.39)	80.35 (32.07)	1.45	0.16	0.23
Digit-span, forward[e]	7.00 (1.29)	8.20 (1.64)	2.53	0.02	0.38
Digit-span, backward[e]	6.11 (1.82)	8.75 (2.53)	3.73	<0.01	0.52
STAI State[f]	41.55 (5.96)	42.50 (4.06)	0.59	0.56	0.10
Follow-up					
BDI[a]	24.00 (11.93)	3.10 (3.26)	−7.38	<0.01	0.85
HAMD[b]	13.53 (7.83)	0.75 (1.55)	−6.98	<0.01	0.85
d2[c]	134.05 (41.88)	161.37 (81.44)	−1.30	0.20	0.24
TMT-A[d] (seconds)	38.42 (13.71)	31.35 (15.26)	1.52	0.15	0.24
TMT-B[d] (seconds)	85.26 (26.27)	82.50 (33.79)	0.28	0.78	0.05
Digit-span, forward[e]	7.00 (2.13)	8.50 (1.79)	2.38	0.02	0.36
Digit-span, backward[e]	6.84 (1.86)	8.25 (2.83)	1.83	0.08	0.29
STAI State[f]	42.80 (6.45)	44.06 (4.07)	0.73	0.47	0.13

Depression severity was assessed using the self-rating [a] Beck Depression Inventory (BDI-II) and the [b] Hamilton Depression Rating Scale (HAMD). Visual attention and concentration were assessed using the [c] d2 (Aufmerksamkeits- und Belastungstest d2), visual attention and task-switching were assessed using the [d] TMT-A and TMT-B (trail-making test A, B), and working memory performance was assessed using the [e] digit-span forward and backward test (maximum possible score 14). Anxiety symptoms were assessed by the [f] STAI (State Trait Anxiety Inventory). r coefficients were calculated as measures of effect size. *MDD* major depressive disorder, *HC* healthy controls

significantly larger amount than controls ($M = 4.58$, SD $= 0.71$). The number of subjects that reported suspicions concerning the cover story after completion of the task in the second session did not differ between samples ($\chi^2_{(1)} = 0.31$, $p = 0.31$).

Emotion judgment task

We conducted a repeated measures ANOVA with 'category' (negative, neutral, and positive) and 'treatment' (baseline and follow-up) as within-subject factors, 'group' (MDD patients and controls) as between-subject factor, and the valence rating as the dependent variable and found a significant main effect of 'category' ($F_{(2,\ 72)} = 922.21$, $p < 0.01, \eta^2 = 0.96$) and 'group' ($F_{(1,\ 36)} = 8.91, p < 0.01$, $\eta^2 = 0.20$; Fig. 2). This 'category' effect confirmed the a priori classification of picture valence (positive > neutral > negative). MDD patients exhibited a negative emotional bias, evident in lower-than-normal valence ratings of all stimulus categories. Specifically, post hoc independent *t*-tests revealed lower valence ratings of MDD patients for the negative ($t_{(30.01)} = 3.04$, $p < 0.01$, $r = 0.49$), neutral ($t_{(38)} = -2.01$, $p = 0.025$, $r = 0.31$), and positive ($t_{(38)} = 2.62$, $p = 0.01$, $r = 0.39$) category at baseline and for the positive ($t_{(36)} = 1.72$, $p = 0.047$, $r = 0.28$, one-tailed) category at follow-up. The same analysis for the arousal ratings also yielded a main effect of 'category' ($F_{(1.43,\ 51.60)} = 102.43$, $p < 0.01$, $\eta^2 = 0.74$; negative > positive > neutral) and an interaction effect of 'category'

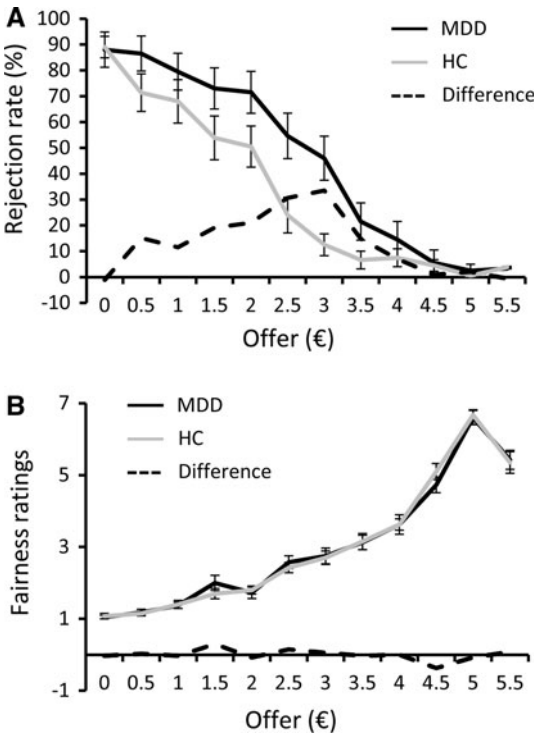

Fig. 1 Results of the ultimatum game task averaged across both sessions. Shown is the rejection rate as a function of offer size (**a**) and fairness ratings of offers (**b**) for patients with major depressive disorder (MDD) and healthy controls (HC). Patients rejected significantly more slightly unfair offers than controls, while groups were indistinguishable in their fairness ratings of these offers. Error bars indicate the standard error of the mean (SEM). *Abbreviations MDD* major depressive disorder, *HC* healthy controls

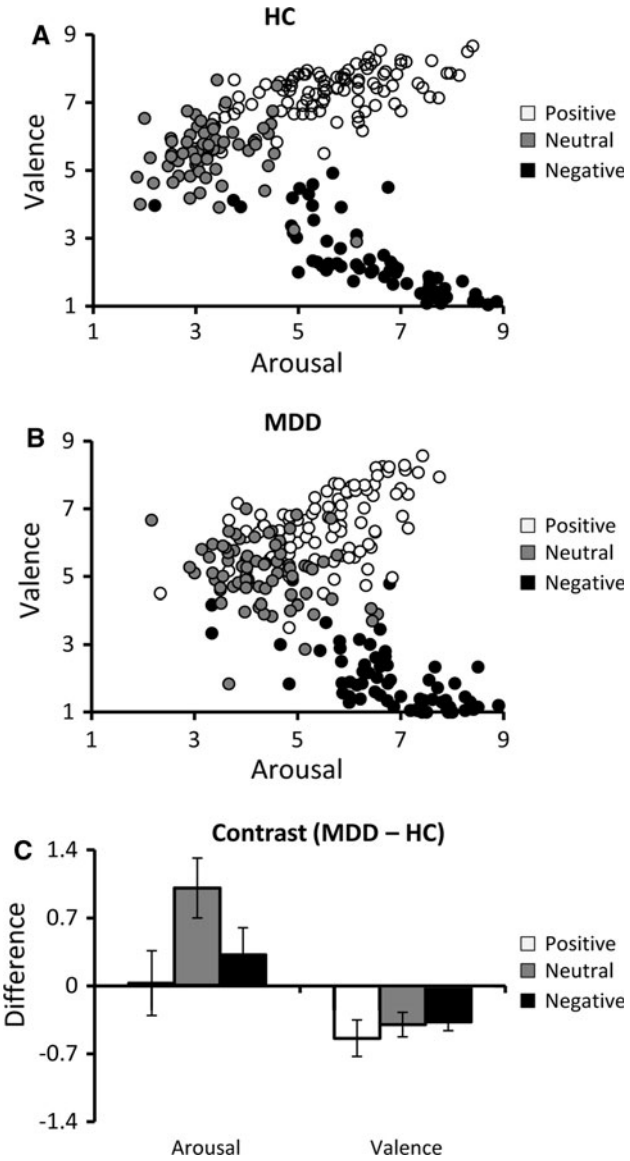

Fig. 2 Results of the emotion judgment task averaged across both sessions. Shown are the emotion ratings obtained from healthy controls (HC) (**a**) and patients with major depressive disorder (MDD) (**b**) as well as the mean difference profile resulting from contrasting both samples, illustrating the illness-related distortion of affective space (**c**). A single data point corresponds to the average response of the 20 HC or 20 MDD patients to a single pictorial item. In both sessions, MDD patients exhibited a negative emotional bias evident in lower-than-normal valence ratings of all stimulus categories. Error bars indicate the standard error of the mean (SEM). *Abbreviations MDD* major depressive disorder, *HC* healthy controls

and 'group' ($F_{(1.43,\ 51.60)} = 3.14$, $p < 0.03$, $\eta^2 = 0.08$, one-tailed). Post hoc independent *t*-tests showed that this interaction was driven by larger arousal ratings of MDD patients for neutral stimuli at baseline ($t_{(38)} = -1.92$, $p = 0.03$, $r = 0.30$, one-tailed) and at follow-up ($t_{(36)} = -2.74$, $p < 0.01$, $r = 0.42$, one-tailed). Again, as in the UG task, there was neither a significant difference between the baseline and follow-up emotional ratings (p's > 0.78), nor a significant difference between responders and non-responders (p's > 0.15).

Associations between clinical measures and behavioral indices

Since there were no significant effects of treatment on UG decisions and emotion judgments, correlational analyses were carried out on the basis of mean scores across baseline and follow-up sessions in order to obtain more robust results. We therefore computed the mean rejection rate for very (0–2.50 €) and slightly (3–4.50 €) unfair offers in the UG and the SED for each valence category as a composite score of emotional bias. While the rejection rate for very unfair offers was similar between patients ($M_{MDD} = 81.42 \pm 28.25$) and controls ($M_{HC} = 71.29 \pm 23.70$; $t(38) = -1.22$, $p = 0.23$, $r = 0.19$), we found a highly significant difference for the slightly unfair offers ($M_{MDD} = 34.16 \pm 30.97$; $M_{HC} = 12.66 \pm 17.24$; $t(38) = -2.71$, $p = 0.01$, $r = 0.40$). The SED of negative ($M_{MDD} = 2.85 \pm 3.18$; $M_{HC} = 1.48 \pm 1.23$; $t(24.53) = -1.79$, $p = 0.04$, $r = 0.34$) and positive pictures ($M_{MDD} = 3.72 \pm 2.55$; $M_{HC} = 2.15 \pm 2.51$; $t(38) = -1.96$, $p = 0.03$, $r = 0.30$, one-tailed) were significantly larger for MDD patients than for controls, and there was no significant effect in the neutral category ($M_{MDD} = 3.74 \pm 2.55$; $M_{HC} = 2.88 \pm 4.28$; $t(38) = -0.76$, $p = 0.23$, $r = 0.12$, one-tailed). Both measures of depression severity were associated with higher rejection rates of very unfair (HAMD: $r = 0.31$, $p = 0.025$, one-tailed; BDI: $r = 0.32$, $p = 0.02$, one-tailed) and slightly unfair offers (HAMD: $r = 0.42$, $p < 0.01$; BDI: $r = 0.28$, $p = 0.04$, one-tailed), with a more pronounced emotional bias for negative (HAMD: $r = 0.29$, $p = 0.04$, one-tailed; BDI: $r = 0.30$, $p = 0.03$, one-tailed) and positive stimuli (HAMD: $r = 0.35$, $p = 0.03$; BDI: $r = 0.27$, $p = 0.05$, one-tailed), a larger motor (HAMD: $r = 0.42$, $p < 0.01$; BDI: $r = 0.34$, $p = 0.02$, one-tailed) and cognitive impulsivity (HAMD: $r = 0.41$, $p < 0.01$; BDI: $r = 0.51$, $p < 0.01$), as well as a higher state anxiety (HAMD: $r = 0.72$, $p < 0.01$; BDI: $r = 0.66$, $p < 0.01$). The only other variable predicting the UG behavior was the emotional bias for negative pictures which correlated with the rejection rate of very unfair offers ($r = 0.27$, $p = 0.047$, one-tailed) and the state anxiety which correlated with the rejection rate of slightly unfair offers ($r = 0.30$, $p = 0.03$, one-tailed).

Discussion

The present study shows for the first time that MDD patients over-sanction social norm violations both at the beginning and after 6 weeks of inpatient treatment. Specifically, MDD patients displayed a negative emotional bias in that they rated emotional stimuli as more negative and also rejected significantly more moderately unfair offers than HC. These data are consistent with the notion that altruistic punishment is driven by a negative emotional response to perceived unfairness and that this reaction is enhanced by depressed mood. Our findings thus extend current perspectives on negative cognitive biases in MDD. Historically rooted in Emil Kraepelin's diagnostic criteria for the distinction between schizophrenia and manic depressive disorder [47], one of the currently most influential conceptual views on the pathomechanism of MDD considers the blunted emotional response to positive stimuli as a central feature [48, 49]. In line with this, the MDD patients tested in our study rated positive pictures as less pleasant than HC. However, their emotion judgment bias was not only restricted to the positive category as they also rated negative items as more unpleasant—a result which is consistent with current views emphasizing potentiated emotional reactivity to negative stimuli as a core feature of MDD [50, 51]. This theory could also account for our observation of elevated arousal ratings for neutral items. Previous studies have shown that, unlike healthy subjects, individuals with MDD do not perceive neutral stimuli as unambiguous signals of emotional neutrality. It thus appears plausible that the neutral stimuli administered in our task elicited higher arousal ratings due to a mood-congruent negative over-interpretation of the picture content [52–54]. Importantly, it has also been reported that a negative emotional bias persists after remission of clinical symptoms [54], which is consistent with the observed deviation in rejection rates and emotion judgments even after improvement in the depressive symptom load following 6 weeks of treatment. Moreover, it has also been proposed that the acceptance of UG offers could be seen as an example of affiliative tendencies [55] and thus a reduced social approach behavior in MDD patients could be reflected in higher rejection rates. In this regard, our findings are partially compatible with a third account arguing that MDD is characterized by an emotional context insensitivity occurring in the form of a generally diminished reactivity to emotional cues [56]. This theory is derived from an evolutionary perspective suggesting an adaptive function of MDD such as fostering withdrawal and disengagement from commitment to unreachable goals [57]. However, we only observed an association between UG decisions and the emotional bias for negative stimuli, and the enhanced arousal ratings

obtained for neutral material also argue against this concept. Hence, the most parsimonious explanation of our findings would probably be to assume that the emotional reaction to negative stimuli including unfair proposals in the UG is unspecifically potentiated in MDD patients.

While fair and extremely unfair offers evoke emotional reactions which appear unaffected by bottom or ceiling effects, proposals located at the middle of the continuum may evoke enhanced negative emotional responses as a consequence of MDD. This effect is similar to neutral stimuli being rated as more unpleasant by MDD patients, hence leading to higher rejection rates. The only previous study investigating altruistic punishment in MDD patients failed to find a significantly biased responders' behavior in the UG [13]. However, this negative finding was based on a version of the UG comprising only three gradual types of unfair offers which may be insensitive to detect behavioral differences related to moderately unfair offers. Our findings thus demonstrate the validity of testing a wide range of offer sizes covering the entire fairness spectrum. Since fairness of the proposed share is critical for the emotional reaction to it, our finding of a linear relationship between fairness perception and offer size indicates that a large variety of different offers are indeed needed. Our results also point to an important discrepancy between high-risk populations displaying subclinical depressive syndromes, as examined by Harlé et al. [12], and clinical cohorts which manifest MDD, as tested in our study. While a lower rejection rate of unfair offers has been documented in the former, the severe sanctions of moderate unfairness observed in our study suggest a breakdown of negative emotion regulation in established clinical states. Furthermore, when acting as proposers, MDD patients tend to offer a significantly larger amount of money, perhaps reflecting an enhanced anxious anticipation of rejection due to inappropriate feelings of guilt and worthlessness [58].

Interestingly, the MDD patients' responder behavior mimics the exaggerated irrational decision-making profile exhibited by patients with damage to the ventromedial prefrontal cortex (vmPFC) [59], and it has been proposed that this behavioral aberrance may reflect an impaired capacity to properly inhibit negative emotions (but see also [60]). Altered responses of the vmPFC have also been identified in several neuroimaging studies of MDD patients [61] and may perhaps contribute to the findings of the present study. On a more theoretical level, our data lend further support for a dual-process approach distinguishing between an affective (irrational) and a deliberative (rational) component of decision making [62]. Unfair offers in the UG are thought to induce a conflict between both systems, and the rejection bias displayed by the MDD patients may indicate a preponderance of the affective mode.

One limitation of the present study is perhaps that the tested MDD patients received antidepressant pharmacotherapy, such that we cannot exclude that our results could reflect an interaction between disease-related and medication-related effects. However, single-dose administration of the benzodiazepine oxazepam [26] or the SSRI citalopram [33] to healthy volunteers has led to opposite findings in the form of decreased rejection rates of unfair offers. The absence of differences in the UG behavior between responsive and non-responsive patients indicates that the observed decision-making bias may constitute an inherent trait characteristic of MDD. In addition, future studies are also warranted to elucidate to what extent a higher rejection rate of unfair offers in the UG is mediated by changes in impulsivity and anxiety often associated with MDD.

In summary, compared to HC, depressed patients oversanctioned unfair proposals in the UG task and judged emotional stimuli too negatively. We thus conclude that major depression is associated with a negative emotional bias that interferes with social–economic decision making and produces large personal costs.

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Conflict of interest None.

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