CORRESPONDENCE

Amygdala Lesion Profoundly Alters Altruistic Punishment

To the Editor:

Human decision making is not guided by rational imperatives alone but is strongly susceptible to and framed by the influence of irrational factors (1). An exquisite example is altruistic punishment, which means the human propensity to punish unfairness, even at a personal cost (2), and helps to sustain cooperation in human societies (3). Experimentally, altruistic punishment has often been operationalized using the socioeconomic ultimatum game (UG). In this task, the responder's rejections of unfair offers are thought to reflect altruistic punishment because by punishing the proposer for unfair offers, the responder also forfeits earnings (4). Rejection rates to unfair offers vary as a function of central serotonergic activity (5,6) and are biased in individuals with depressed mood ([7], but see [8]), schizophrenia ([9,10], but see [11]), and psychopathy (12). The evidence suggests that altruistic punishment is driven by negative emotions toward noncooperators (2). Consistent with this notion, single-dose administration of a benzodiazepine has been shown to decrease altruistic punishment as well as associated amygdala responses (13). Although lesion studies have often implicated the amygdala as a core generator of negative emotional arousal and emphasized its crucial role in mediating loss aversion during monetary gambles (14-16), a direct demonstration of a causal role of the amygdala in modulating altruistic punishment is still missing.

In the current study, we used the lesion method to test the hypothesis that judgments of emotional arousal and valence, as well as altruistic punishment in the UG, are causally linked to and influenced by amygdala function. Two 36-year-old female monozygotic twins with equivalent selective bilateral amygdala calcification damage following lipoid proteinosis of Urbach-Wiethe (17–19) and 12 healthy female controls (mean age $\pm$ SD = 33.3 $\pm$ 3.87 years) volunteered after providing written informed consent. The study was approved by the Institutional Review Board of the Medical Faculty of the University of Bonn. In previous behavioral, psychophysiological, and functional magnetic resonance imaging experiments, we have demonstrated that patient 1 but not patient 2 generated appropriate responses to fear signals, was able to form a normal-sized social network, and also exhibited normal emotional empathy for negatively valenced social stimuli, suggesting that she has developed a partial functional compensation of her amygdala damage, perhaps involving the cortical mirror-neuron system (18,19). In experimental tasks specifically addressing amygdala-hippocampal interactions during encoding of emotional episodic memories, however, both patients were severely impaired compared with controls (17,18). Thus, it would appear that patient 1's compensation for her amygdala damage does not extend to all aspects of amygdala function.

We first tested the twins against controls for their ability to judge emotional arousal and valence of 129 stimuli selected from the International Affective Picture System (IAPS) (20) (experiment 1). To visualize the quality and quantity of deviations from the mean control group ratings (Figure 1A), individual arousal and valence ratings were z-transformed and visually represented as vector maps in a two-dimensional affective space with arousal ratings along the x-axis and valence ratings along the y-axis (Figure 1, B-D). Our results revealed that both twins have lower-than-normal arousal responses to emotional IAPS stimuli (patient 1: negative, $Z = -2.02$, $p = .043$; neutral, $Z = -1.49$, $p > .05$; positive, $Z = -2.63$, $p < .01$; patient 2: negative, $Z = -5.65$, $p < .01$; neutral, $Z = -1.49$, $p > .05$;

positive, $Z = -2.12$, $p < .01$), but only patient 2 additionally displays aberrant valence judgments by rating most of the stimuli as neutral (negative, $Z = 4.59$, $p < .01$; neutral, $Z = -0.53$, $p > .05$; positive, $Z = -3.67$, $p < .01$).

Next, the twins were tested against controls on multiple iterations of the UG with varying levels of fairness (fair, unfair, and most unfair) and monetary stakes (low and high), with 10 offers randomly presented in each condition for a total of 60 trials (experiment 2). Our results revealed a behavioral pattern suggestive of overcompensation in patient 1, including excessive rejection rates for fair offers during high stakes ($Z = 3.18$, $p < .01$; Figure 1F) and significantly longer reaction times across all conditions ($Z = 2.60$, $p < .01$). In stark contrast, patient 2 displayed mostly rational behavior during the UG, i.e. a lack of altruistic punishment (Figure 1E), except during situations of extreme unfairness and high monetary stakes, in which she rejected 100% of the offers (Figure 1F). This dramatic shift to complete rejection of the most unfair offers at high stakes was significantly different from the response profile shown by controls ($Z = -4.05$, $p < .01$) and suggests that patient 2 applied a rule-based all-or-none strategy during the UG. Alternatively, it may take higher stakes and maximal unfairness to induce an arousal response, which would subsequently lead her to altruistic punishment. We note that the observed aberrations in altruistic punishment in both twins were neither due to deviant fairness attitudes (all p values > .18) nor to subjective differences in the perceived fairness of offers (all p values > .11).

In conclusion, our study revealed impoverished emotional arousal ratings and deviant punishment behavior in both lipoid proteinosis of Urbach-Wiethe patients. Compared with patient 1, who in the past has shown relatively intact fear and emotional empathy responses as well as normal social networking abilities (18,19), the deficits observed here were more pronounced in patient 2, who exhibited aberrant arousal and valence judgments and who punished almost exclusively when emotional arousal and pecuniary interest were increased by raising the stakes in the UG. Taken together, our results provide evidence not only for the relevance of the amygdala in both emotional valence and arousal judgments but also the first causal evidence that altruistic punishment, an evolutionary important domain of socioeconomic decision making, is modulated by the amygdala. Thus, our findings corroborate the notion of altruistic punishment being an emotion-driven and impulsive act of retaliation.

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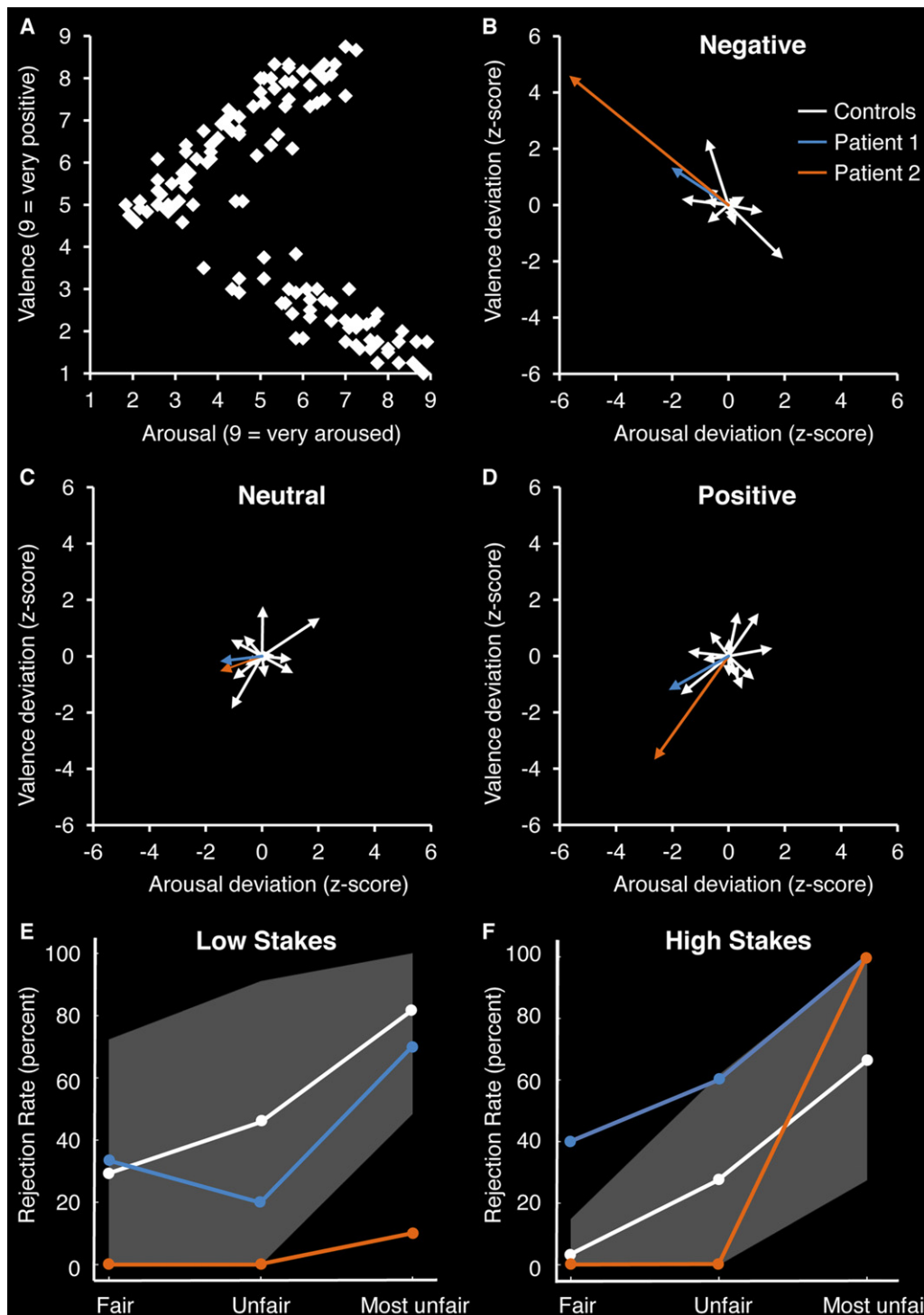
Figure 1. Emotion ratings **(A-D)** and ultimatum game decisions **(E, F)**. **(A)** Arousal and valence ratings in the control group for 129 stimuli selected from the International Affective Picture System (IAPS), forming the characteristic "boomerang" shape of affective space (20). Vector maps for negative **(B)**, neutral **(C)**, and positive **(D)** IAPS stimuli, illustrating deviant arousal ratings in both patients and deviant valence ratings in patient 1. Rejection rates of unfair offers in the ultimatum game in percent (mean ± 1 SD as indicated by the grey area for controls) for the low **(E)** and high **(F)** stakes conditions, demonstrating deviant altruistic punishment in both patients.

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