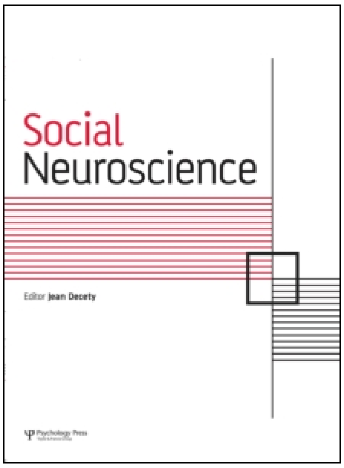

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Fairness concerns predict medial frontal negativity amplitude in ultimatum bargaining

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Fairness concerns predict medial frontal negativity amplitude in ultimatum bargaining

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Despite evidence that anterior cingulate cortex (ACC) activity is related to social exclusion, rejection and unfairness, evidence that medial frontal negativity (MFN), which has its source in the ACC, reflects these constructs remains unforthcoming. In the present study, subjects participated as recipients in an ultimatum game, while we recorded their electro-encephalogram (EEG). Participants responded to fair and unfair offers from different human proposers. In addition, participants rated themselves on a measure evaluating their concern for fairness. Results showed that MFN amplitude was more pronounced for unfair offers compared to fair offers. Moreover, this effect was shown to be most pronounced for subjects with high concerns for fairness. Our findings suggest that the MFN not only reflects whether outcomes match expectations, but also reflects whether the process by which these outcomes came about matches a social or even a moral norm. In addition, the present results suggest that people in bargaining situations are not only concerned with their own outcomes, but are also concerned with the fairness of the process that resulted in these outcomes.

Keywords: Fairness; Ultimatum game; MFN; FRN; ACC; ERP.

INTRODUCTION

Modern-day humans tend to live in very large groups and therefore have to be able to cooperate with many different people, most of whom will probably never be encountered again. To be able to cooperate in this manner, people should make decisions that are not always purely self-serving, but should also be concerned with outcomes for others (Gintis, Bowles, Boyd, & Fehr, 2003). Indeed, adhering to a general norm of fairness appears to be critical for the development of successful cooperation in larger groups of individuals (Fehr & Schmidt, 1999). This ‘‘sense of fairness’’ has been show to prevail in a wide variety of circumstances (Fehr & Rockenbach, 2003), in various different cultures (Henrich et al., 2006) and in different age groups (Murnighan & Saxon, 1998).

The ultimatum game (UG; Güth, Schmittberger, & Schwarze, 1982) is widely used to examine responses to unfairness. In the UG, one of two players (the proposer) receives a sum of money which he is to divide between himself and the other player (the recipient). The proposer can split the money any way he wants and can even opt to keep everything for himself. The recipient can then either accept or reject the offer. When he accepts, the money is divided as proposed. If the recipient rejects, however, both players receive nothing. In either event, the game ends there and then; there will be no further interaction between the players. Standard economic models of decision-making (game theory; Von Neuman & Morgenstern, 1944) predict that a rational recipient should accept any offer (something is better than nothing) and the proposer, knowing this, should propose the smallest offer

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possible. Although this outcome is considered economically optimal (none of the players can unilaterally increase their payoff, the so-called Nash Equilibrium; Nash, 1950), this is not how real people behave. In reality, recipients reject offers of 20% of the total sum about half of the time. Moreover, proposers appear to take this behavior into account and usually offer a 50/50 split (e.g. Bolton & Zwick, 1995; Nowak, Page, & Sigmund, 2000).

In recent years, the emergence of what has become popularly known as neuroeconomics (Camerer, Loewenstein, & Prelec, 2005) has generated a surge of research efforts focused on the neural correlates of this seemingly irrational decision-making process (see e.g. Lee, 2006; Sanfey, 2007; Sanfey, Loewenstein, McClure, & Cohen, 2006). The first study to focus on the neural systems involved in playing the recipient in the UG was that of Sanfey and coworkers (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). Using functional magnetic resonance imaging (fMRI), they showed that receiving unfair offers was associated with increased activations in the dorsolateral prefrontal cortex, anterior cingulate cortex (ACC) and the insula. The authors interpreted their findings as reflecting the recipients' negative emotional response to unfair offers. Indeed, the insula has been shown to be involved in the experience of negative emotional states (Calder, Lawrence, & Young, 2001), in particular disgust (Phillips et al., 1997) and aversive bodily states (Craig, 2003).

Although Sanfey and coworkers interpreted their finding of increased ACC activation upon receiving unfair offers solely in terms of reflecting the conflict between the rational and the emotional response to unfair offers, research indicates that the ACC is also involved in the affectively aversive components of both physical and social pain. Neurologists have known for many years (Foltz & White, 1968) that cingulotomy (i.e. the removal of parts of the cingulate cortex) alleviates pain in the sense that while patients still report feeling the pain after surgery, it no longer bothers them, indicating the role of the ACC in the affective rather than the sensory aspects of pain (Price, 2000; Rainville, Duncan, Price, Carrier, & Bushnell, 1997; Tolle et al., 1999). More recently, involvement of the ACC in pain processing has been extended to also include social pain, such as the "pain" resulting from being excluded by peers (Eisenberger & Lieberman, 2004; Eisenberger, Lieberman, & Williams, 2003). Findings that ACC activity in response to disapproving facial expressions is positively related to individual differences in rejection sensitivity (Burklund, Eisenberger, & Lieberman, 2007) also indicate the involvement of the ACC in the processing of social pain.

In addition, and perhaps relatedly, the ACC is involved in the processing of outcomes that deviate in a negative way from expectations (reward prediction errors; Amiez, Joseph, & Procyk, 2005; Matsumoto, Matsumoto, Abe, & Tanaka, 2007). Activity in the ACC increases when experimental subjects commit errors (Ullsperger, Nittono, & Von Cramon, 2007), but also increases when performance feedback is provided that indicates that outcomes are below expectations (e.g. Nieuwenhuis, Schweizer, Mars, Botvinick, & Hajcak, 2007). Indeed, one of the most prominent theories in this literature (Holroyd & Coles, 2002) suggests that ACC activity reflects that outcomes are not as good as expected, which seems particularly relevant for interpreting ACC activations upon receiving low offers in the UG.

A family of negative-going event-related potentials (ERPs) with a dipole source in the ACC (Dehaene, Posner, & Tucker, 1994; Gehring & Willoughby, 2002) has been shown to reflect these reward prediction errors, both when subjects commit errors (error-related negativity (ERN); Falkenstein, Hohnsbein, Hoormann, & Blanke, 1990; Gehring, Coles, Meyer, & Donchin, 1990) and when subjects receive negative performance feedback (feedback-related negativity (FRN); Miltner, Braun, & Coles, 1997). These ERP components have been suggested to be associated with common neural processes (Luu, Tucker, Derryberry, Reed, & Poulsen, 2003; Nieuwenhuis, Holroyd, Mol, & Coles, 2004), and for convenience, we will refer to these components as medial frontal negativity (MFN; Gehring & Willoughby, 2002). The MFN has been proposed to reflect the activity of a system for reinforcement learning (Holroyd & Coles, 2002). The reinforcement learning theory of the MFN holds that this system utilizes information obtained from rewards and punishments (or non-rewards), as well as from indicators of success and failure, in order to adjust behavior and select the appropriate responses for achieving goals. In addition, the MFN has been proposed to reflect a motivational/affective evaluation of negative outcomes (Boksem, Tops, Kostermans, & De Cremer, 2008; Boksem, Tops, Wester, Meijman, & Lorist, 2006; Bush, Luu, & Posner, 2000; Gehring & Willoughby, 2002; Hajcak, Moser, Yeung, & Simons, 2005; Masaki, Takeuchi, Gehring, Takasawa, & Yamazaki, 2006; Pailing & Segalowitz, 2004; Yu, Luo, Ye, & Zhou, 2007).

However, despite evidence that ACC activity is related to social exclusion, rejection and unfairness, evidence that MFN actually reflects these constructs remains largely unforthcoming (although see Boksem et al., 2008; Cavanagh & Allen, 2008; Tops, Boksem, Wester, Lorist, & Meijman, 2006; Tucker, Luu, Frishkoff, Quiring, & Poulsen, 2003). This is unfortunate because such findings would provide valuable insights into the underlying processes reflected in MFN, which is a widely used measure of decision-making, and would provide an initial step towards extending the large literature on MFN and decision-making to the social domain. In addition, such findings would provide researchers with an easily obtainable (compared to fMRI) measure to study decision-making in a social context.

In the present study, we had subjects participate as recipients in a version of the UG, while we recorded their electro-encephalogram (EEG). Participants responded to fair and unfair offers from different human proposers. In addition, to confirm that neural activations in response to low UG offers do indeed reflect emotional responses to violations of a fairness norm specifically, we also took account of individual differences in the subjective importance that people attach to fairness. Research shows that there may be substantial differences in how highly individuals value fairness (Van Dijk, De Cremer & Handgraaf, 2004). Indeed, most models of fairness assume that only some people have a preference for fairness (e.g. Falk & Fishbacher, 2006; Rabin, 1993). Taking this into account, aversive neural responses to unfair offers should be especially prominent for subjects who value fairness and moral norms highly.

To examine to what extent subjects consider fairness and moral decision-making an important concern, we used Aquino and Reed's (2002) Moral Identity instrument as a dispositional measure of a sense of fairness. The Moral Identity measure identifies how subjects value concepts such as fairness, generousness, helpfulness, and honesty. An emerging stream of research in social and organizational psychology shows that moral identity plays a key role in moral functioning because it influences how people interpret and respond to situations involving moral judgment and choice (see Shao, Aquino, & Freeman, 2008 for a review). It has been shown (Aquino, Freeman, Reed, Lim, & Felps, in press) that a high moral identity is related to increased importance of fairness considerations and reduced motivations that are purely self-interested. Based on these findings we expect that if a recipient scores high on moral identity, he or she will be more sensitive to principles of fairness in a social exchange such as the UG. Therefore, we predicted that MFN amplitudes elicited by unfair offers would be particularly pronounced for subjects scoring high on the Moral Identity measure.

METHODS

Subjects

Seventeen healthy participants (seven males), between 18 and 32 ($M = 21.5$, $SD = 3.4$) years of age, were recruited from the university population. They were either paid for their participation or received course credit. All had normal or corrected-to-normal vision. Three subjects described themselves as being left-handed. Written informed consent was obtained prior to the study.

Moral identity measure

We used the 10-item Moral Identity instrument developed by Aquino and Reed (2002) to measure this construct. The instrument has two subscales of five items each: Moral Internalization and Moral Symbolization. According to Aquino and Reed, the Internalization subscale captures the degree to which a person's moral identity is rooted at the core of one's being. This subscale appears to be the most robust predictor of morally relevant behavior (Aquino & Reed, 2002; Reed & Aquino, 2003). The Symbolization subscale, on the other hand, is proposed to tap a more general sensitivity to the moral self as a social object whose actions in the world can convey that one has these moral characteristics. Respondents answered each item on a seven-point Likert scale (1 = strongly disagree; 7 = strongly agree).

Task

Participants acted as recipients in a series of 48 trials of the UG. In half of these trials, the participant was first presented with a picture of a person about to make an ultimatum offer, and a text indicating that this person received €20 from the experimenter, for 4 s. The other half of the trials were identical, except that a picture of a computer was presented instead of a person, indicating that subjects were not interacting with a real person. Data from these computer trials will not be discussed in the present paper. Next, the participant saw the offer (e.g., "Offers you €4"), for 3 s. Following these 3 s, the participant saw "Accept or Reject?" on the screen. The participant had unlimited time to consider the offer and push the corresponding button ("Accept" or "Reject"). Finally, the participant was informed about the outcome based on his/her response (e.g., "You get €0, other gets €0" when the offer was rejected or "You get €4, other gets €16" when the offer was accepted. The intertrial interval was 4 s.

Participants received 24 offers from different human proposers (12 males, 12 females). Before the start of the experiment, the participants were instructed about the contingencies of an "Accept" or "Reject" response; that the offers were real, made by other subjects who participated previously; that the participant's responses would not affect subsequent offers, and that both the participant and the proposer would be paid according to the outcome of one randomly selected trial. In reality, the 24 pictured "proposers" were pictures from the NimStim Face Stimulus set (MacArthur Foundation Research Network) and the offers were predetermined. Payment, however, did proceed according to the one randomly selected trial.

All participants received the same 24 offers in a fixed random order. Subjects received twelve €10 (other gets €10) offers, five €6 (other gets €14) offers, four €4 (other gets €16) offers, and three €2 (other gets €18) offers from the different proposers. Prior research shows that equality is a pervasive and very salient decision heuristic in this kind of game. As such, violations of equality are usually regarded as unfair (Messick, 1995). Because people generally consider equal distributions (i.e. a 50/50 split) fair (Van Dijk et al., 2004) and because offers less then 35% of the total sum are mostly rejected (Güth et al., 1982), we considered the €10 offers to be fair and lower offers to be unfair, resulting in an equal number of fair and unfair offers.

Procedure

Before the start of the experiment, subjects were given written task instructions and were asked to fill out the questionnaire. They then completed five practice trials to get acquainted with the task. For added realism, subjects were informed that the proposers they encountered during the task were in fact subjects who had participated previously and that these subjects would be paid according to the choices made by the present participant. To increase credibility, subjects were also asked to indicate on a form how much money they themselves would offer in an UG situation. We then asked whether the participant would also like to act as a proposer for following participants (and be able to earn extra money). If the participant agreed (which they all did), we took their photograph to include in future instantiations of the experiment. In reality, only pictures from the NimStim Face Stimulus set were ever used in the experiment and photographs of subjects were immediately deleted.

Electrophysiological recording and data reduction

Electroencephalographic recordings (EEG) were made on 43 locations using active Ag–AgCl electrodes (Biosemi ActiveTwo, Amsterdam, Netherlands) mounted in an elastic cap. Horizontal EOGs were recorded from two electrodes placed at the outer canthi of both eyes. Vertical EOGs were recorded from electrodes on the infraorbital and supraorbital regions of the right eye placed in line with the pupil. The EEG and EOG signals were sampled at a rate of 256 Hz, digitally low-pass filtered with a 52 Hz cut-off (3 dB) and offline rereferenced to an averaged mastoid reference.

All ERP analyses were performed using the Brain Vision Analyser software (Brain Products). The data were resampled at 100 Hz and further filtered with a 0.53 Hz high-pass filter and a slope of 48 dB/oct and a 40 Hz low-pass filter also with a slope of 48 dB/oct. Artifacts were rejected and eye movement artifacts were corrected, using the Gratton, Coles and Donchin (1983) method. After artifact rejection, on average 11.8 trials (out of a possible 12) per condition remained for further analyses. ERPs from each individual subject and condition were averaged separately and a baseline voltage averaged over the 200 ms interval preceding events of interest was subtracted from these averages.

Electrophysiological data analyses

To minimize the effects of overlap of the MFN with other ERP components, we created difference waves (see Holroyd and Krigolson, 2007; Holroyd, Pakzad-Vaezi, & Krigolson, 2008) by subtracting the ERPs elicited by fair offers from the ERPs elicited by unfair offers. Visual inspection of grand-averaged difference waveforms and their scalp distributions (Figures 1 and 2) indicated a MFN that reached its maximum at a latency of 320 ms after presentation of the offer on multiple frontal electrode sites, centered around Fz and apparently displaying a lateralization to the right hemisphere, reaching its maximum at AF4 for unfair offers. Therefore, we used data from these two electrodes (Fz and AF4) for further analyses. Because peak detection proved to be unreliable in individual subject data, we submitted the average ERP difference wave amplitude in a time window of 300–350 ms post offer presentation, where visual inspection showed the MFN to have its maximum, to paired-samples *t*-tests. In addition, the individual difference measure of Moral Identity was correlated with average difference wave amplitudes.

RESULTS

Performance

Unfair offers were rejected in 65% of the cases, while fair offers were almost never rejected. Subjects indicated that they, on average, would offer €8.09 ($SD = 2.12$) if they themselves would act as the proposer in the UG. Eight out of the 17 subjects proposed €10, which is the 50/50 split, while none of the subjects proposed more than €10 or less then €4. The size of this offer was found to be unrelated to their rejection rates, but

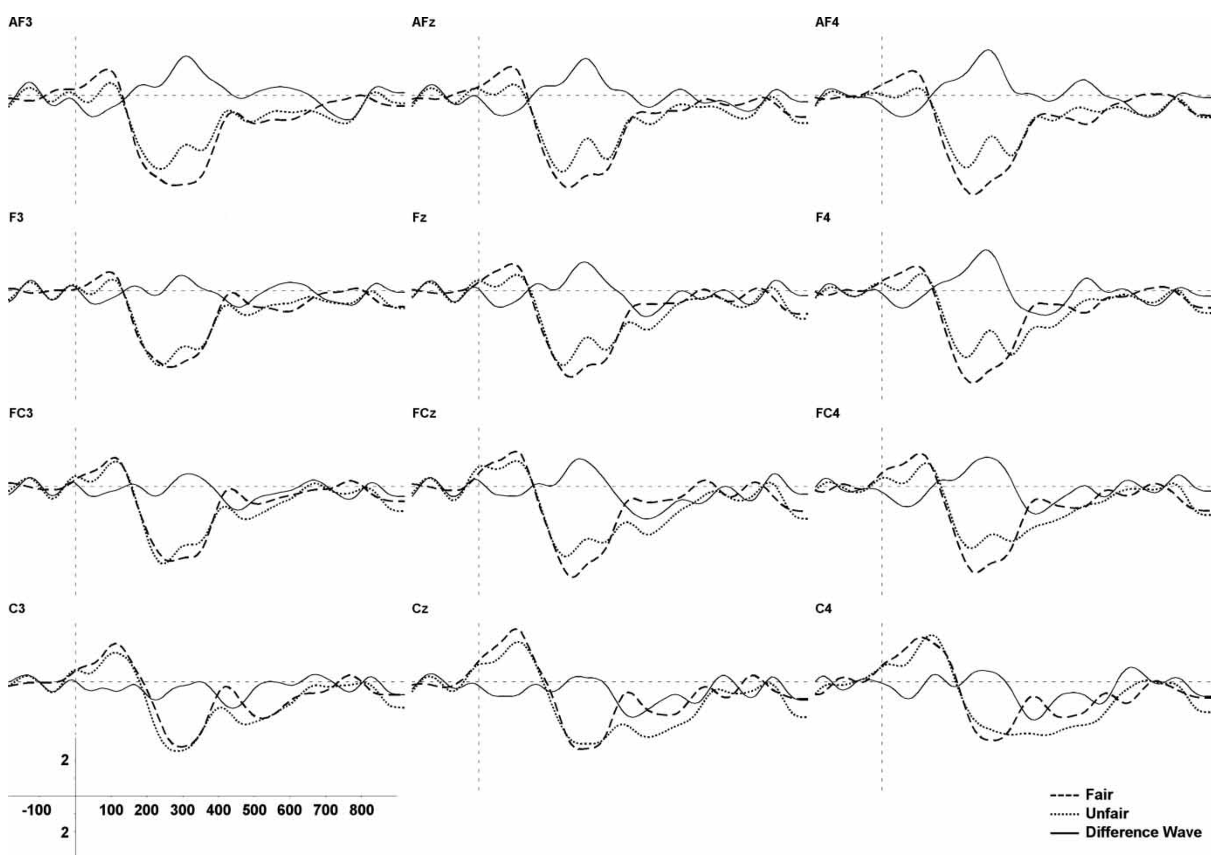

Figure 1. ERPs elicited by fair (dashed line) and unfair (dotted line) offers and the associated difference wave (solid line). Note that negative is plotted upwards and amplitudes are in μV.

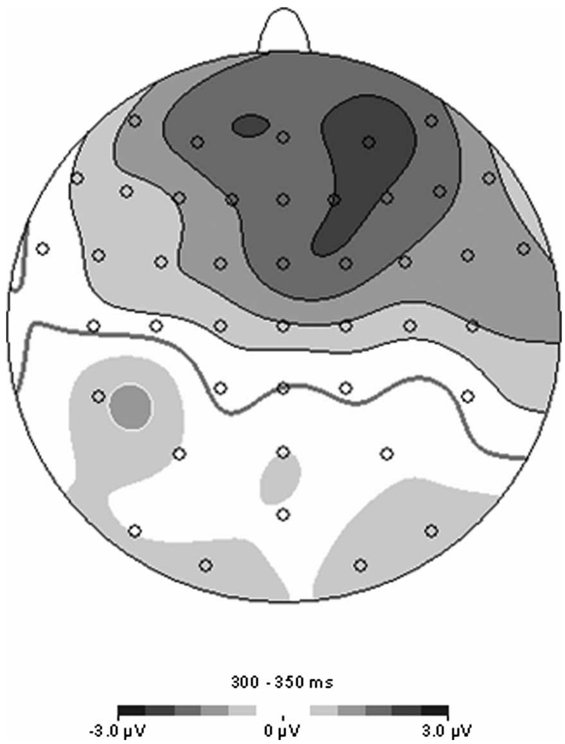

Figure 2. Scalp topography of the difference in MFN amplitude between fair and unfair offers. Topography map is shown for the interval selected for analysis.

showed a positive correlation with Moral Symbolization, $r(17) = .53$, $p < .05$, indicating that subjects high on Moral Symbolization said they would offer more.

ERPs

Figure 1 shows the ERPs elicited by fair and unfair offers and the associated difference wave. Unfair offers elicited a more negative-going deflection compared to fair offers, resulting in a negative-going difference wave in the time interval of interest. As can be seen in Figures 1 and 2, this difference wave had a right-frontal maximum on AF4 (-2.88 µV). One-sample t-tests revealed that this fairness effect was significantly different from zero, $t(16) = -3.21$, $p < .005$ on AF4, but not on Fz, $t(16) = -1.71$, *ns.* Importantly, this effect was related to individual differences in Moral Identity: Subjects scoring high on Moral Identity displayed the largest MFN in response to unfair offers. This is visualized in Figure 3a, displaying the correlation between Moral Identity and the MFN difference between fair and unfair offers on AF4, $r(17) = -.70$, $p < .005$. MFN amplitude was similarly correlated with Moral Identity on Fz, $r(17) = -.57$, $p < .05$ (see Figure 3b). In contrast, MFN amplitude was found to be unrelated to rejection rates, $r(17) = .24$, n.s., on AF4, and also just failed to reach significance for Fz, $r(17) < .44$, $p > .08$.

DISCUSSION

The ACC has been shown to be involved in evaluating whether outcomes are different from expectations: Increases in ACC activity are observed when subjects commit errors, when feedback indicates that expected rewards have failed to materialize, or when subjects incur financial losses (punishments). In addition, ACC activity has been associated with losses and punishments in the social domain, such as being rejected by peers or being treated unfairly. The MFN has been proposed to be generated in the ACC and has been shown to reflect the neural activity that is associated with error commission, receiving negative feedback and incurring financial losses. However, until now the MFN has not been related to negative outcomes in the social domain. In the present experiment, subjects played the UG in the role of recipient, experiencing fair and unfair outcomes (high and low human-generated offers).

The results showed that MFN amplitude was most pronounced on trials involving unfair offers compared to that evoked by fair offers, indicating that this component reflects negative social outcomes in the present experimental setting. Important additional evidence for this interpretation is provided by the observed relationship between MFN amplitude evoked by unfair offers and Moral Identity scores. Subjects who value moral norms such as fairness and honesty highly, displayed larger MFN amplitudes when evaluating unfair offers compared to subjects with less regard for such moral norms. Taken together, these results provide compelling evidence that the MFN, like the ACC, reflects negative outcomes of a social nature such as unfair treatment by others. These findings may add to previous results showing enhanced MFN activity when subjects observe others experiencing disadvantageous outcomes (Hewig et al., 2008; Van Schie, Mars, Coles, & Bekkering, 2004), which may be related to socio-emotional processes such as empathy (Fukushima & Hiraki, 2006).

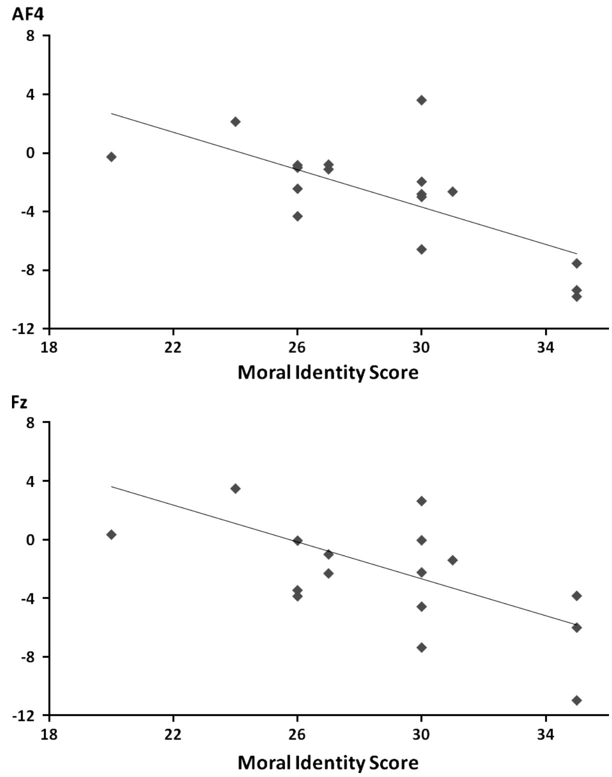

Figure 3. Correlation between Moral Identity (Internalization subscale) scores and the difference in MFN amplitude (in μV) elicited by fair and unfair offers on AF4 (top panel) and Fz (bottom panel).

Recently, Holroyd et al. (2008) showed that the MFN can be regarded as an N200, which is an ERP component that is elicited by unexpected or task-relevant events, of which feedback is just a specific instance. In our study, subjects may have experienced unfair offers by human proposers as relatively unexpected or relevant, thereby eliciting an MFN. Indeed, it has been shown that the MFN covaries with the subjective probability of the outcome (Bellebaum & Daum, 2008; Hajcak, Moser, Holroyd, & Simons, 2007). This interpretation also corroborates the idea that recipients in a UG expect fair offers from their fellow participants, suggesting that humans indeed adhere to a fairness norm. The MFN, in turn, is elicited when this fairness norm has been violated. Subjects scoring high on Moral Identity, and thus having a strong internalized norm of fairness, may have higher expectations of their fellow men than subjects low on Moral Identity. Therefore, especially for these subjects, low offers may be experienced as significantly different from expectations. As a consequence, these subjects display the largest MFN amplitudes when confronted with unfairness. In addition, MFN amplitude has been shown to reflect a motivational/affective evaluation of outcomes (Gehring & Willoughby, 2002; Masaki et al., 2006; Yu et al., 2007). That is, the subjective value of the outcome appears to be reflected in the MFN. For example, Forbes, Schmader, and Allen (2008) recently showed that when students performed a task that was supposedly indicative of intelligence, MFN amplitude could be predicted by how highly students valued academics. So, especially for subjects who value fairness and honesty, outcomes that violate their norm of fairness evoke a negative affective response that is reflected in their MFN amplitudes. This is very much reminiscent of the "social pain" that has been associated with ACC activity, which is the putative source of the MFN.

The present study adds in an important way to previous neuroimaging work. While the high spatial resolution of fMRI used in the study by Sanfey and coworkers (2003) provides significant insights into the neural structures involved in ultimatum bargaining, the slow time course of the BOLD response makes it rather difficult to distinguish between processes related to the evaluation of fair and unfair offers and the intention to accept or reject these offers. For example, the insula activation in their study may have reflected the negative affect subjects experienced upon receiving unfair offers (see Calder et al., 2001), but may also have reflected aversion to the anticipated loss of money that would result from rejecting unfair offers (see Knutson, Rick, Wimmer, Prelec & Loewenstein, 2007). Their observed correlation between insula activity and acceptance rates may be considered to be in favor of the latter interpretation. In contrast, the high temporal resolution of ERPs allowed us to evaluate processes that are specifically locked to the evaluation of fair and unfair offers. Observed at 300 ms after presentation of the offer, the MFN is clearly elicited by the evaluation of the offer, while (occurring some 3 s later) response preparation or outcome anticipation is unlikely to have affected MFN amplitude. In addition, our finding that MFN is more strongly related to a dispositional measure such as Moral Identity than to behavioral measures may also indicate that it is the evaluative component of (un)fairness that is reflected in this measure.

In the literature on fairness and justice research, there has been some disagreement whether recipients in UG bargaining are actually concerned with fairness or instead are only concerned with their own (low) outcome (e.g. Güth & Van Damme, 1998; Pillutla & Murnighan, 1996, 2003; Falk, Fehr, & Fischbacher, 2003). Partly because research in this literature has primarily focused on the allocator and not on the recipient (Handgraaf, Van Dijk, & De Cremer, 2003), this issue has yet to be resolved. The present data provides compelling evidence that recipients in a bargaining situation are concerned not only with their own financial outcome but also with the process that led to this outcome. That is, low outcomes were particularly experienced as ‘‘painful’’ when they were considered to be unfair. Possibly reflecting this ‘‘social pain’’, MFN amplitude was particularly enhanced when subjects who actually value fairness and honesty, as indicated by their Moral Identity scores, were confronted with low offers. Therefore, it appears that fairness concerns do indeed play a major role in ultimatum bargaining situations.

There are some limitations to the present study. First, in studying social interactions with ERPs, there is always a trade-off between obtaining a sufficient number of trials in each condition and maintaining the credibility of the social interaction: Subjects will probably find it very hard to believe they are having this interaction with hundreds of different individuals. Therefore, we chose to present our subjects with a limited number of interactions. The drawback of this approach is that we end up with a limited number of trials, prohibiting more detailed analyses. For example, it would have been interesting to see whether the MFN amplitude would actually be correlated with the level of unfairness of the offer, with €2 offers generating larger MFNs than €6 offers. In fact, in a recent ERP study using the UG with many more trials than the current experiment, Polezzi and coworkers (2008) showed that especially mid-value offers (such as €6) generate the largest negative ERP deflections. Although the Polezzi study suffers from its own limitations (they failed to find MFN differences between high and low offers), this finding does indicate that it would be useful to employ a larger number of trials in future studies. Finally, for an ERP component called medial frontal negativity, we find a remarkable lateral topographical distribution of this component, especially for unfair human offers. Although a right lateralization of the MFN has been reported in previous studies (e.g. Gehring and Willoughby, 2002; Masaki et al., 2006), in the present study this occurred to a rather large extent. Importantly, this lateralization was present in all subjects and was not due to artifacts in the EEG recordings of a few subjects. In the EEG literature, there is quite some evidence that avoidance-related negative affect is associated with greater right-sided frontal activity (Henriques & Davidson, 1990; Amodio et al., 2004). In the present study, receiving unfair offers is likely to generate negative affect and a tendency to inhibit approach behavior (not accepting the offer), which may result in increased right-frontal activity. Although the relationship between EEG and ERP measures is not at all clear, these observations may partly explain the right lateralization of the MFN in this study. The findings by Sanfey and colleagues (2003), reporting the largest fMRI signal changes in specifically the right DLPFC and right insula for unfair offers by human proposers, also appears to support our findings. However, interpretations of this lateralization of the MFN have to remain speculative at this point. Future studies, preferably using denser electrode arrays, will have to show what the underlying neural mechanism for this lateralization may be.

To conclude, our findings suggest that the MFN, like its ACC source, not only reflects whether outcomes match expectations, but also reflects whether the process by which these outcomes came about matches social or moral norms.

In addition, the present results suggest that people in bargaining situations are not only concerned with their own outcomes, but are also, and perhaps primarily, concerned with the fairness of the process that resulted in these outcomes.

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REFERENCES

Amiez, C., Joseph, J. P., & Procyk, E. (2005). Anterior cingulate error-related activity is modulated by predicted reward. *European Journal of Neuroscience*, *21*(12), 3447–3452.

Amodio, D. M., Shah, J. Y., Sigelman, J., Brazy, P. C., & Harmon-Jones, E. (2004). Implicit regulatory focus associated with asymmetrical frontal cortical activity. *Journal of Experimental Social Psychology*, *40*(2), 225–232.

Aquino, K., & Reed, A. (2002). The self-importance of moral identity. *Journal of Personality and Social Psychology*, *83*(6), 1423–1440.

Aquino, K., Freeman, D., Reed, A., Lim, V., & Felps, W. (in press). When morality matters: Moral identity and the self-regulation of behaviour. *Journal of Personality and Social Psychology*.

Bellebaum, C., & Daum, I. (2008). Learning-related changes in reward expectancy are reflected in the feedback-related negativity. *European Journal of Neuroscience*, *27*(7), 1823–1835.

Boksem, M. A. S., Tops, M., Kostermans, E., & De Cremer, D. (2008). Sensitivity to punishment and reward omission: Evidence from error-related ERP components. *Biological Psychology*, *79*, 185–192.

Boksem, M. A. S., Tops, M., Wester, A. E., Meijman, T. F., & Lorist, M. M. (2006). Error-related ERP components and individual differences in punishment and reward sensitivity. *Brain Research*, *1101*, 92–101.

Bolton, G. E., & Zwick, R. (1995). Anonymity versus punishment in ultimatum bargaining. *Games and Economic Behavior*, *10*(1), 95–121.

Burklund, L. J., Eisenberger, N. I., & Lieberman, M. D. (2007). The face of rejection: Rejection sensitivity moderates dorsal anterior cingulate activity to disapproving facial expressions. *Social Neuroscience*, *2*(3–4), 238–253.

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, *4*(6), 215–222.

Calder, A. J., Lawrence, A. D., & Young, A. W. (2001). Neuropsychology of fear and loathing. *Nature Reviews Neuroscience*, *2*(5), 352–363.

Camerer, C., Loewenstein, G., & Prelec, D. (2005). Neuroeconomics: How neuroscience can inform economics. *Journal of Economic Literature*, *43*(1), 9–64.

Cavanagh, J. F., & Allen, J. J. B. (2008). Multiple aspects of the stress response under social evaluative threat: An electrophysiological investigation. *Psychoneuroendocrinology*, *33*(1), 41–53.

Craig, A. D. (2003). Interoception: The sense of the physiological condition of the body. *Current Opinion in Neurobiology*, *13*(4), 500–505.

Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a neural system for error-detection and compensation. *Psychological Science*, *5*(5), 303–305.

Eisenberger, N. I., & Lieberman, M. D. (2004). Why rejection hurts: A common neural alarm system for physical and social pain. *Trends in Cognitive Sciences*, *8*(7), 294–300.

Eisenberger, N. I., Lieberman, M. D., & Williams, K. D. (2003). Does rejection hurt? An fMRI study of social exclusion. *Science*, *302*(5643), 290–292.

Falk, A., Fehr, E., & Fischbacher, U. (2003). On the nature of fair behavior. *Economic Inquiry*, *41*(1), 20–26.

Falk, A., & Fischbacher, U. (2006). A theory of reciprocity. *Games and Economic Behavior*, *54*(2), 293–315.

Falkenstein, M., Hohnsbein, J., Hoormann, J., & Blanke, L. (1990). Effects of errors in choice reaction tasks on the ERP under focussed and divided attention. In C. H. M. Brunia, A. W. K. Gaillard, & A. Kok (Eds.), *Psychophysiological brain research* (pp. 192–195). Tilburg, The Netherlands: Tilburg University Press.

Fehr, E., & Rockenbach, B. (2003). Detrimental effects of sanctions on human altruism. *Nature*, *422*(6928), 137–140.

Fehr, E., & Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *Quarterly Journal of Economics*, *114*(3), 817–868.

Foltz, E. L., & White, L. E. (1968). The role of rostral cingulotomy in 'pain' relief. *International Journal of Neurology*, *6*, 353–373.

Forbes, C. E., Schmader, T., & Allen, J. J. B. (2008). The role of devaluing and discounting in performance monitoring: A neurophysiological study of minorities under threat. *Social Cognitive and Affective Neuroscience*, *3*, 253–261.

Fukushima, H., & Hiraki, K. (2006). Perceiving an opponent's loss: Gender-related differences in the medial-frontal negativity. *Social Cognitive and Affective Neuroscience, 1*, 149–157.

Gehring, W. J., Coles, M. G. H., Meyer, D. E., & Donchin, E. (1990). The error-related negativity: An event-related brain potential accompanying errors. *Psychophysiology*, *27*, 34.

Gehring, W. J., & Willoughby, A. R. (2002). The medial frontal cortex and the rapid processing of monetary gains and losses. *Science*, *295*(5563), 2279–2282.

Gintis, H., Bowles, S., Boyd, R., & Fehr, E. (2003). Explaining altruistic behavior in humans. *Evolution and Human Behavior*, *24*(3), 153–172.

Gratton, G., Coles, M. G., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, *55*, 468–484.

Güth, W., Schmittberger, R., & Schwarze, B. (1982). An experimental analysis of ultimatum games. *Journal of Economic Behavior and Organization*, *3*, 367–388.

Güth, W., & Van Damme, E. (1998). Information, strategic behaviour and fairness in ultimatum bargaining. *Journal of Mathematical Psychology*, *42*, 227–247.

Hajcak, G., Moser, J. S., Holroyd, C. B., & Simons, R. F. (2007). It's worse than you thought: The feedback negativity and violations of reward prediction in gambling tasks. *Psychophysiology*, *44*(6), 905–912.

Hajcak, G., Moser, J. S., Yeung, N., & Simons, R. F. (2005). On the ERN and the significance of errors. *Psychophysiology*, *42*(2), 151–160.

Handgraaf, M. J. J., Van Dijk, E., & De Cremer, D. (2003). Social utility in ultimatum bargaining. *Social Justice Research*, *16*(3), 263–283.

Henrich, J., McElreath, R., Barr, A., Ensminger, J., Barrett, C., Bolyanatz, A., et al. (2006). Costly punishment across human societies. *Science*, *312*(5781), 1767–1770.

Henriques, J. B., & Davidson, R. J. (1990). Regional brain electrical asymmetries discriminate between previously depressed and healthy control subjects. *Journal of Abnormal Psychology*, *99*(1), 22–31.

Hewig, J., Trippe, R. H., Hecht, H., Coles, M. G. H., Holroyd, C. B., & Miltner, W. H. R. (2008). An electrophysiological analysis of coaching in Blackjack. *Cortex*, *44*(9), 1197–1205.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review*, *109*(4), 679–709.

Holroyd, C. B., & Krigolson, O. E. (2007). Reward prediction error signals associated with a modified time estimation task. *Psychophysiology*, *44*(6), 913–917.

Holroyd, C. B., Pakzad-Vaezi, K. L., & Krigolson, O. E. (2008). The feedback correct-related positivity: Sensitivity of the event-related brain potential to unexpected positive feedback. *Psychophysiology*, *45*(5), 688–697.

Knutson, B., Rick, S., Wimmer, G. E., Prelec, D., & Loewenstein, G. (2007). Neural predictors of purchases. *Neuron*, *53*, 147–156.

Lee, D. Y. (2006). Neural basis of quasi-rational decision making. *Current Opinion in Neurobiology*, *16*(2), 191–198.

Luu, P., Tucker, D. M., Derryberry, D., Reed, M., & Poulsen, C. (2003). Electrophysiological responses to errors and feedback in the process of action regulation. *Psychological Science*, *14*(1), 47–53.

Masaki, H., Takeuchi, S., Gehring, W. J., Takasawa, N., & Yamazaki, K. (2006). Affective–motivational influences on feedback-related ERPs in a gambling task. *Brain Research*, *1105*, 110–121.

Matsumoto, M., Matsumoto, K., Abe, H., & Tanaka, K. (2007). Medial prefrontal cell activity signaling prediction errors of action values. *Nature Neuroscience*, *10*(5), 647–656.

Messick, D. M. (1995). Equality, fairness, and social conflict. *Social Justice Research*, *8*, 153–173.

Miltner, W. H. R., Braun, C. H., & Coles, M. G. H. (1997). Event-related brain potentials following incorrect feedback in a time-estimation task: Evidence for a ''generic'' neural system for error detection. *Journal of Cognitive Neuroscience*, *9*(6), 788–798.

Murnighan, J. K., & Saxon, M. S. (1998). Ultimatum bargaining by children and adults. *Journal of Economic Psychology*, *19*(4), 415–445.

Nash, J. (1950). Equilibrium points in *n*-person games. *Proceedings of the National Academy of Sciences of the United States of America*, *36*(1), 48–49.

Nieuwenhuis, S., Holroyd, C. B., Mol, N., & Coles, M. G. H. (2004). Reinforcement-related brain potentials from medial frontal cortex: Origins and functional significance. *Neuroscience and Biobehavioral Reviews*, *28*(4), 441–448.

Nieuwenhuis, S., Schweizer, T. S., Mars, R. B., Botvinick, M. M., & Hajcak, G. (2007). Error-likelihood prediction in the medial frontal cortex: A critical evaluation. *Cerebral Cortex*, *17*(7), 1570–1581.

Nowak, M. A., Page, K. M., & Sigmund, K. (2000). Fairness versus reason in the Ultimatum Game. *Science*, *289*(5485), 1773–1775.

Pailing, P. E., & Segalowitz, S. J. (2004). The error-related negativity as a state and trait measure: Motivation, personality, and ERPs in response to errors. *Psychophysiology*, *41*(1), 84–95.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., et al. (1997). A specific neural substrate for perceiving facial expressions of disgust. *Nature*, *389*(6650), 495–498.

Pillutla, M. M., & Murnighan, J. K. (1996). Unfairness, anger, and spite: Emotional rejections of ultimatum offers. *Organizational Behavior and Human Decision Processes*, *68*(3), 208–224.

Pillutla, M. M., & Murnighan, J. K. (2003). Fairness in bargaining. *Social Justice Research*, *16*(3), 241–261.

Polezzi, D., Daum, I., Rubaltelli, E., Lotto, L., Civai, C., Sartori, G., et al. (2008). Mentalizing in economic decision-making. *Behavioural Brain Research*, *190*, 218–223.

Price, D. D. (2000). Psychological and neural mechanisms of the affective dimension of pain. *Science*, *288*(5472), 1769–1772.

Rabin, M. (1993). Incorporating fairness into game-theory and economics. *American Economic Review*, *83*(5), 1281–1302.

Rainville, P., Duncan, G. H., Price, D. D., Carrier, B., & Bushnell, M. C. (1997). Pain affect encoded in human anterior cingulate but not somatosensory cortex. *Science*, *277*(5328), 968–971.

Reed, A., & Aquino, K. F. (2003). Moral identity and the expanding circle of moral regard toward out-groups. *Journal of Personality and Social Psychology*, *84*(6), 1270–1286.

Sanfey, A. G. (2007). Social decision-making: Insights from game theory and neuroscience. *Science*, *318*(5850), 598–602.

Sanfey, A. G., Loewenstein, G., McClure, S. M., & Cohen, J. D. (2006). Neuroeconomics: Cross-currents in research on decision-making. *Trends in Cognitive Sciences*, *10*(3), 108–116.

Sanfey, A. G., Rilling, J. K., Aronson, J. A., Nystrom, L. E., & Cohen, J. D. (2003). The neural basis of economic decision-making in the ultimatum game. *Science*, *300*(5626), 1755–1758.

Shao, R., Aquino, K., & Freeman, D. (2008). Beyond moral reasoning: A review of moral identity research and its implications for business ethics. *Business Ethics Quarterly*, *18*, 513–540.

Tolle, T. R., Kaufmann, T., Siessmeier, T., Lautenbacher, S., Berthele, A., Munz, F., et al. (1999). Region-specific encoding of sensory and affective components of pain in the human brain: A positron emission tomography correlation analysis. *Annals of Neurology*, *45*(1), 40–47.

Tops, M., Boksem, M. A. S., Wester, A. E., Lorist, M. M., & Meijman, T. F. (2006). Task engagement and the relationships between the error-related negativity, agreeableness, behavioral shame proneness and cortisol. *Psychoneuroendocrinology*, *31*(7), 847–858.

Tucker, D. M., Luu, P., Frishkoff, G., Quiring, J., & Poulsen, C. (2003). Frontolimbic response to negative feedback in clinical depression. *Journal of Abnormal Psychology*, *112*(4), 667–678.

Ullsperger, M., Nittono, H., & von Cramon, D. Y. (2007). When goals are missed: Dealing with self-generated and externally induced failure. *NeuroImage*, *35*(3), 1356–1364.

Van Dijk, E., De Cremer, D., & Handgraaf, M. J. J. (2004). Social value orientations and the strategic use of fairness in ultimatum bargaining. *Journal of Experimental Social Psychology*, *40*(6), 697–707.

Van Schie, H. T., Mars, R. B., Coles, M. G. H., & Bekkering, H. (2004). Modulation of activity in medial frontal and motor cortices during error observation. *Nature Neuroscience*, *7*(5), 549–554.

Von Neuman, J., & Morgenstern, O. (1944). *Theory of games and economic behavior*. Princeton, NJ: Princeton University Press.

Yu, R. J., Luo, Y. J., Ye, Z., & Zhou, X. L. (2007). Does the FRN in brain potentials reflect motivational/affective consequence of outcome evaluation? *Progress in Natural Science*, *17*, 136–143.