Social status modulates the neural response to unfairness

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Abstract

In human society, which is organized by social hierarchies, resources are usually allocated unequally and based on social status. In this study, we analyze how being endowed with different social statuses in a math competition affects the perception of fairness during asset allocation in a subsequent Ultimatum Game (UG). Behavioral data showed that when divsse(Game)-24two6 p2;,-24b tha0-247.percepw*[(s 9 66.)-246.itusgr4@a(n)]Tt45.3 (of)4 (and)extu@a(n38 (wi926.6 6 if(cooect)-ltimatocated)-24

unequal offers than their lower status counterparts, supporting the perspective that high-status individuals feel entitled to more than low-status individuals in bargaining situations (Ball *et al.*, 2001). Consistent with these studies, in one of our previous studies (Hu *et al.*, 2014), we dynamically manipulated individuals' social status through a simple task and found that individuals reject more unfair offers when endowed with high status than when endowed with low status. Although it is common knowledge that endowment of low status induces negative emotions (Kraus *et al.*, 2011), which make an individual more likely to reject offers in UG (Harlé and Sanfey, 2007), research has shown that deference in low status and entitlement in high status increase the high-status individuals' rejection rate for unfair offers during asset distribution (Albrecht *et al.*, 2013, Hu *et al.*, 2014), which reinforces the importance of a social hierarchy in fairness interactions. In this study, combining our previous paradigm with functional magnetic resonance imaging (fMRI), we aimed to investigate the neural effects of social status -ing

a flip angle of 90° and a field of view of 200 mm × 200 mm, and 3.1 mm × 3.1 mm × 3.1 mm voxels.

fMRI preprocessing

Preprocessing of the fMRI images was done using Statistical Parametric mapping software SPM8 (Wellcome Trust Department of Cognitive Neurology, London, UK), which was run through MATLAB (Mathworks). For each run, the first five volumes were discarded to allow for stabilization of magnetization. Then, the remaining images were slice-time corrected, motion-corrected, re-sampled to $3 \times 3 \times 3$ isotropic voxel, normalized to Montreal Neurological Institute (MNI) space and spatially smoothed using an 8 mm FWHM Gaussian filter. Data were filtered using a high-pass filter with 1/128 Hz cutoff frequency.

General linear model analyses

To analyze how social status influenced the entire decision-making processes, we estimated a general linear model (GLM) of blood-oxygen-level-dependent (BOLD) responses, which combined BOLD responses during the viewing of the UG offer and during the implementation of each UG decision (accept or reject). For the first-level analysis, nine regressors of interest were included in the model for each participant: low status unfair offer, low status sub-fair offer, low status fair offer, middle status unfair offer, middle status sub-fair offer, middle status fair offer, high status unfair offer, high status sub-fair offer and high status fair offer. In addition, we included the onsets of the partner pairing screen and the proposer deciding screen as regressors of no interest in the model. Six head motion parameters were included as regressors of no interest in all models. All regressors of interest were convolved with a canonical hemodynamics response function (HRF). For the second-level group analysis, four beta images of interest (low status unfair offer, low status fair offer, high status unfair offer and high status fair offer) were fed into a flexible factorial model. We defined four contrasts corresponding to the main effects of fairness and status ('Unfair > Fair', 'Fair > Unfair', 'High status > Low status' and 'Low status > High status'). We tested the interaction contrast values '(Low status unfair − Low status fair) − (High status unfair − High status fair)'. We also conducted a one-sample *t*-test for the correlation between the contrast of interest (High status unfair − Low status unfair) and the measure of social status effect (i.e. the increased rejection rate for unfair offers in the high-status condition relative to the low-status condition).

Psycho-physiological interaction analysis

The GLM analysis showed that activity in the right anterior insula (rAI) during the contrast of interest (High status unfair offer − Low status unfair offer) was associated with individual differences in rejection rates during UG. We were interested in the

social status was successful in changing feelings of superiority/inferiority [$F(1, 22) = 97.59$, $P < 0.001$, $\eta^2_{partial} = 0.81$, with participants perceiving themselves as higher in status after attaining three stars (5.26 ± 0.15) than after attaining one star (2.35 ± 0.15). As expected, when compared with low status, participants in high status felt entitled to higher offer amounts as the recipient [$F(1,22) = 12.58$, $P = 0.002$, $\eta^2_{partial} = 0.36$] and to higher allocations to the self while acting as the proposer [$F(1,22) = 10.07$, $P = 0.004$, $\eta^2_{partial} = 0.31$]. In particular, participants evidenced higher minimum acceptable amounts in high status (3.4 ± 0.06) than in low status (3.0 ± 0.06), and indicated that they would allocate to themselves a greater amount while in high status (5.73 ± 0.12) than in low status (4.94 ± 0.12).

The primary behavioral measure was the difference in rejection rates between high and low status. This measure proved to be an effective representation of the behavioral data as it positively correlated with how superior participants reported feeling in the high status condition ($r = 0.46$, $P = 0.028$, $d.f. = 21$) and with participants' self-reports of being influenced by their social status during the UG ($r = 0.82$, $P < 0.001$, $d.f. = 21$). Additionally, it is unlikely that this measure was confounded by participant social status outside the experiment, as it was not correlated with either objective (i.e. socioeconomic status) or subjective social status (parent highest level education, $P = 0.6$; annual family income, $P = 0.35$; subjective social status, $P = 0.74$).

fMRI results

To confirm our results with past findings on UG, we estimated a GLM of the BOLD responses during the UG offer encoding process. We first identified voxels that were more activated for unfair UG offers than for fair UG offers. Consistent with past research (Sanfey *et al.*, 2003, van den Bos *et al.*, 2010), there was a main effect of unfairness, with greater activation for unfair offers than for fair offers in the ACC, which extended to the supplementary motor area/middle cingulate cortex (SMA/MCC; Figure 3A and Table 1), and in the DLPFC (Figure 3B). It is surprising that we found no insula activation during the unfair > fair contrast; however, if we relax our threshold ($P < 0.005$, minimum cluster extent = 46 voxels, a threshold of corrected $P < 0.05$ according to AlphaSim), we did find significant activity in the left AI ($x = -39$, $y = 11$, $= -8$, Mas T-value = 3.10, $k = 75$). There was no significant activation for

resulted from changes in hormone and neurotransmitter levels while occupying different social statuses. Changes in social status have been shown to influence the neuroendocrine system (Chiao, 2010; Knight and Mehta, 2014; Zilioli *et al.*, 2014). For example, changes in social status affect testosterone levels of individuals in a hierarchy (Zilioli *et al.*, 2014). Moreover, manipulation of hormone and neurotransmitter levels can change amygdala responses to positive and negative stimuli. In a recent study, Aupperle *et al.* (2011) showed that the amygdala exhibits a stronger activation during the anticipation of positive stimuli than during the anticipation of negative stimuli; additionally, Pregabalin, an anxiolytic which decreases the levels of certain neurotransmitters, can reverse this amygdala activation pattern. Given these findings, we speculate that the difference

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Supplementary data

Supplementary data are available at *SCAN* online.

Conflict of interest. None declared.

References

Adler, N.E., Epel, E.S., Castellazzo, G., Ickovics, J.R. (2000). Relationship of subjective and objective social status with psychological and physiological functioning: preliminary data in healthy white women. *Health Psychology*, **19**, 586–92.

Albrecht, K., von Essen, E., Fliessbach, K., Falk, A. (2013). The influence of status on satisfaction with relative rewards. *Frontiers in Psychology*, **4**, 804.

Aupperle, R.L., Lakshmi, R., Tankersley, D., *et al.* (2011). Pregabalin influences insula and amygdala activation during anticipation of emotional images. *Neuropsychopharmacology*, **36**(7), 1466–77.

Ball, S., Eckel, C., Grossman, J., Zame, W. (2001). Status in markets. *Quarterly Journal of Economics*, **116**, 161–88.

Blader, L., Chen, Y. (2012). Differentiating the effects of status and power: a justice perspective. *Journal of Personality and Social Psychology*, **102**, 994–1014.

Boksem, A., Kostermans, E., Milivojevic, B., De Cremer, D. (2012). Social status determines how we monitor and evaluate our performance. *Social Cognitive and Affective Neuroscience*, **7**, 304–13.

Chiao, J. (2010). Neural basis of social status hierarchy across species. *Current Opinion in Neurobiology*, **20**(6), 803–9.

Civai, C., Crescentini, C., Rustichini, A., Rumiati, R.I. (2012). Equality versus self-interest in the brain: differential roles of anterior insula and medial prefrontal cortex. *Neuroimage*, **62**, 102–12.

Corradi-Dell'Acqua, C., Civai, C., Rumiati, R.I., Fink, G.R. (2013). Disentangling self- and fairness-related neural mechanisms involved in the ultimatum game: an fMRI study. *Social Cognitive and Affective Neuroscience*, **8**(4), 424–31.

Craig, A.D. (2009). How do you feel now? The anterior insula and human awareness. *Nature Reviews Neuroscience*, **10**(1), 59–70.

Dulebohn, J.H., Conlon, D.E., Sarinopoulos, I., Davison, R.B., McNamara, G. (2009). The biological bases of unfairness: neuroimaging evidence for the distinctiveness of procedural and distributive justice. *Organizational Behavior and Human Decision Processes*, **110**(2), 140–51.

Feng, C., Luo, Y., Krueger, F. (2015). Neural signatures of fairness-related normative decision making in the ultimate game: a coordinate-based meta-analysis. *Human Brain Mapping*, **36**(2), 591–602.

Flynn, F.J., Reagans, R.E., Amanatullah, E.T., Ames, D.R. (2006). Helping one's way to the top: self-monitors achieve status by helping others and knowing who helps whom. *Journal of Personality and Social Psychology*, **91**(6), 1123–37.

Friston, K.J., Buechel, C., Fink, G.R., Morris, J., Rolls, E., Dolan, R.J. (1997). Psychophysiological and modulatory interactions in neuroimaging. *Neuroimage*, **6**(3), 218–29.

Gabay, A.S., Radua, J., Kempton, M.J., Mehta, M.A. (2014). The Ultimatum Game and the brain: A meta-analysis of neuroimaging studies. *Neuroscience and Biobehavioral Reviews*, **47**, 549–58.

Gospic, K., Mohlin, E., Fransson, P., Petrovic, P., Johannesson, M., Ingvar, M. (2011). Limbic justice—amygdala involvement in immediate rejection in the Ultimatum Game. *PLoS Biology*, **9**(5), e1001054.

Grosenick, L., Clement, T.S., Fernald, R.D. (2007). Fish can infer social rank by observation alone. *Nature*, **445**(7126), 429–32.

Guinote, A., Cotzia, I., Sandhu, S., Siwa, P. (2015). Social status modulates prosocial behavior and egalitarianism in preschool children and adults. *Proceedings of the National Academy of Sciences*, **112**(3), 731–6.

Güroğlu, B., van den Bos, W., Rombouts, S.A.R.B., Crone, E.A. (2010). Unfair? It depends: neural correlates of fairness in social context. *Social Cognitive and Affective Neuroscience*, **5**, 414–23.

Güth, W., Schmittberger, R., Schwarze, B. (1982). An experimental analysis of ultimatum bargaining. *Journal of Economic Behavior and Organization*, **3**, 367–88.

Haber, S.N., Calzavara, R. (2009). The cortico-basal ganglia integrative network: the role of the thalamus. *Brain Research Bulletin*, **78**, 69–74.

Harlé, M., Sanfey, G. (2007). Incidental sadness biases social economic decisions in the ultimatum game. *Emotion*, **7**, 876–81.

Haruno, M., Frith, C.D. (2010). Activity in the amygdala elicited by unfair divisions predicts social value orientation. *Nature Neuroscience*, **13**(2), 160–1.

Hu, J., Cao, Y., Blue, P.R., Zhou, X. (2014). Low social status decreases the neural salience of unfairness. *Frontiers in Behavioral Neuroscience*, **8**, 402.

King-Casas, B., Sharp, C., Lomax-Bream, L., Lohrenz, T., Fonagy, P., Montague, P.R. (2008). The rupture and repair of cooperation in borderline personality disorder. *Science*, **321**(5890), 806–10.

Klumpp, H., Angstadt, M., Phan, K.L. (2012). Insula reactivity and connectivity to anterior cingulate cortex when processing threat in generalized social anxiety disorder. *Biological Psychology*, **89**(1), 273–6.

Knight, E.L., Mehta, P.H. (2014). Hormones and hierarchies. In: Cheng, J.T., Tracy, J.L., Anderson, C., editors. *The Psychology of Social Status*. New York: Springer, pp. 269–301.

Knoch, D., Nitsche, M.A., Fischbacher, U., Eisenegger, C., Pascual-Leone, A., Fehr, E. (2008). Studying the neurobiology of social interaction with transcranial direct current stimulation—the example of punishing unfairness. *Cerebral Cortex*, **18**(9), 1987–90.

Piff, K., Kraus, W., Côté, S., Cheng, H., Keltner, D. (2010). Having less, giving more: the influence of social class on prosocial behavior. *Journal of Personality and Social Psychology,* **99**, 771–84.

Piff, K., Stancato, M., Côté, S., Mendoza-Denton, R., Keltner, D. (2012). Higher social class predicts increased unethical behavior. *Proceedings of the National Academy of Sciences,* **109**, 4086–91.

Rabb, G.B., Woolpy, J.H., Ginsburg, B.E. (1967). Social relationships in a group of captive wolves. *American Zoologist,* **7**(2), 305–11.

Radke, S., Güroğlu, B., de Bruijn, E.R.A. (2012). There's something about a fair split: intentionality moderates context-based fairness considerations in social decision-making. *PLoS One,* **7**(2), 1–6.

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**