

Acting on Social Exclusion: Neural Correlates of Punishment and Forgiveness of Excluders

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Supplementary material

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Supplementary tables

Supplementary table 1

Brain regions revealed by whole-brain contrasts during the Cyberball game (all thresholded $p < .001$ uncorrected, > 10 voxels).

Anatomical region	L/R	Voxels	z	MNI coordinates		
				x	y	z
Exclusion no ball > Inclusion ball						
Calcarine gyrus/Cuneus	L	783	5.45	-15	-93	-6*
			4.85	15	-99	6*
			4.69	18	-93	15*
Precuneus/Lingual gyrus	L	85	4.76	-6	-57	12*
			3.45	-15	-63	-6*
Middle Temporal gyrus	L	134	4.42	-51	9	-30*
			4.31	-54	0	-24*
			3.66	-60	-9	-18*
Medial Prefrontal cortex	R	45	3.85	3	45	-15*
			3.47	-12	57	-6*
Subgenual Anterior Cingulate cortex	L	15	3.79	-9	24	-6*
			3.47	0	27	-9*
Lingual gyrus	L	16	3.61	-18	-39	-12*
<i>Positive correlation with need satisfaction after the exclusion game</i>						
Superior Frontal gyrus	L	22	4.37	-18	24	54
Ventral Anterior Cingulate cortex	R	35	4.30	6	42	3
Inferior Frontal gyrus/Anterior Insula	R	19	3.71	45	21	-3

Positive correlation with self-reported perspective-taking skills

No significant clusters of activation

Positive correlation with need satisfaction after the exclusion game

No significant clusters of activation

Inclusion ball > Exclusion no ball

Inferior Parietal lobule extending into:	L	5059	6.42	-36	-39	45*
Postcentral gyrus	R		6.33	33	-33	48*
Postcentral gyrus	L		6.32	-33	-33	54*
Middle Temporal gyrus extending into:	L	280	5.06	-45	-66	0*
Middle Occipital gyrus			4.43	-51	-75	0*
			3.70	-33	-99	-6*
Middle Temporal gyrus	R	364	4.87	48	-66	-3*
			4.79	48	-57	3*
			4.42	60	-63	-3*
Insula (mid) extending into:	L	200	4.80	-39	-3	9*
Inferior Frontal gyrus			4.70	-51	9	0*
			4.27	-54	9	21*
Middle Cingulate cortex	L	58	4.76	-12	-24	42*
Cerebellum Crus 1	R	95	4.66	39	-57	-30*
			3.48	51	-57	-33*
			3.26	30	-69	-30*
Inferior Frontal gyrus	R	286	4.60	57	9	9*
			4.38	57	12	21*
			4.37	54	12	-6*
Thalamus	L	27	4.46	-9	-24	6*
			4.02	-12	-12	3*
Middle Occipital gyrus	R	41	4.29	33	-78	30*
Middle Frontal gyrus	L	151	4.14	-36	39	15*
			3.96	-27	36	24*
			3.84	-42	39	27*
Thalamus	R	17	4.08	12	-18	6*
Insula	L	18	4.07	-33	21	6*
Middle Frontal gyrus	R	98	3.98	33	42	36*
			3.70	36	45	24*
Middle Cingulate cortex	R	10	3.69	9	-18	45*
Cerebellum 6	L	27	3.69	-33	-57	-30*

Exclusion no ball > Inclusion no ball

Caudate	L	11	3.90	-3	12	0
Cuneus	L	25	3.74	-6	-93	15
Middle Cingulate cortex	R	30	3.74	3	-30	21
			3.37	3	-21	33
Lingual gyrus	R	20	3.65	18	-45	-3
Cuneus	R	11	3.41	3	-78	27

Inclusion no ball > Exclusion no ball

Precuneus	R	174	4.76	12	-66	60*
			4.06	-12	-63	60*
Inferior Parietal Lobule	L	155	4.41	-42	-45	48*
			3.58	-54	-33	48*
			3.46	-27	-45	51*
Superior Temporal gyrus	R	45	4.33	66	-42	12*
			3.83	63	-36	21*
Middle Frontal gyrus	R	79	4.28	30	0	51*
			4.01	30	3	63*
			3.67	33	9	57*
Inferior Frontal gyrus	L	11	4.08	-33	33	9
Middle Temporal gyrus	R	140	4.06	57	-69	0*
			3.88	54	-60	6*
			3.70	45	-63	0*
Inferior Frontal gyrus	R	41	3.87	54	9	21*
Inferior Parietal lobule/ Superior Parietal lobule	R	69	3.77	42	-42	51*
			3.58	42	-45	60*
Middle Temporal gyrus	L	58	3.75	-51	-72	9*
			3.63	-42	-66	6*
Superior Frontal gyrus/ Middle Frontal gyrus	L	28	3.65	-24	-9	63
			3.59	-30	0	54
Inclusion no ball > Inclusion ball						
Cuneus/Calcarine gyrus	R	333	5.89	18	-102	9*

			3.94	9	-93	30*
			3.64	15	-81	9*
Middle Occipital gyrus	L	208	4.86	-24	-99	15*
			4.60	-15	-96	-9*
			4.43	-18	-105	12*
Middle Temporal gyrus	L	55	4.31	-51	6	-33*
			3.60	-51	-3	-30*
			3.58	-57	-12	-24
Inferior Frontal gyrus	R	21	4.10	42	33	-15*
Inferior Frontal gyrus	L	13	3.87	-39	33	-15
Inclusion ball > Inclusion no ball						
Inferior Parietal lobule extending into:	L	5283	6.59	-42	-30	42*
Supramarginal gyrus/			6.36	-60	-24	42*
Supplementary Motor Area			6.27	-12	-9	66*
Inferior Frontal gyrus extending into:	R	1898	6.02	51	9	0*
Insula	L		5.88	-45	3	-3*
Thalamus	L		5.39	-12	-18	9*
Cerebellum 6	R	219	5.03	33	-60	-27*
			3.59	30	-72	-27*
Inferior Temporal gyrus	R	266	4.91	42	63	-6*
			4.39	39	-54	-3*
Middle Temporal gyrus	R		3.97	51	-54	0*
Cerebellum 6	L	154	4.69	-33	-51	-30*
			4.61	-21	-54	-24*
Middle Occipital gyrus	L	142	4.47	-45	-69	0*
Middle Frontal gyrus	L	75	4.08	-33	39	30*
			3.77	-27	33	30*
			3.37	-39	45	15*
Middle Frontal gyrus	R	76	3.94	33	45	33*
			3.67	39	45	27*
			3.62	33	39	27*
Vermis 4 5	R	20	3.93	3	-60	-9*

Precuneus	L	46	3.73	-9	-75	42*
Superior Occipital gyrus			3.47	-21	-72	30*
Superior Parietal gyrus			3.14	-18	-66	39*

Note. L/R=Left/Right; k=cluster size in 3×3×3mm voxels; Z=z-score; MNI coordinates =xyz voxel coordinates in MNI space of the peak voxel. Ball = events on which participants received the ball; No ball = events where participants did not receive the ball. * = also significant using FDR correction, $p < .05$, > 10 voxels).

Supplementary table 2

Brain regions revealed by whole-brain analyses testing for sex differences for the contrast Excluders > Includers in the Dictator Game (all thresholded $p < .001$ uncorrected, > 10 voxels).*

Anatomical region	L/R	Voxels	z	MNI coordinates		
				x	y	z
Males [Excluders - Includers] > Females [Excluders - Includers]						
Middle Temporal gyrus	L	125	4.35	-51	0	-21

Note. L/R=Left/Right; k=cluster size in 3×3×3mm voxels; Z=z-score; MNI coordinates =xyz voxel coordinates in MNI space of the peak voxel.

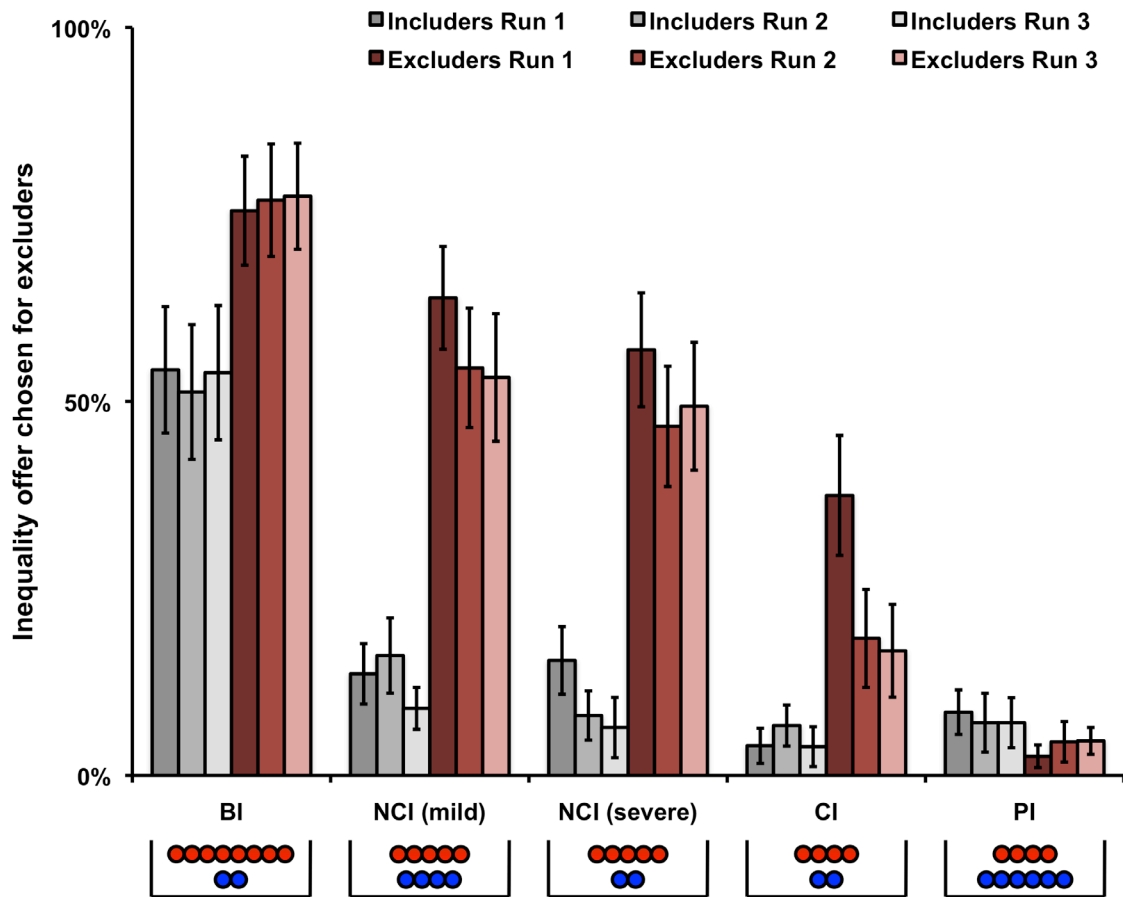
*We explored sex differences in all reported whole-brain contrasts. Direct comparisons between males and females on the Cyberball, punishment (Inequality excluders > Equality excluders) and Forgiveness (Equality excluders > Equality includers) contrasts did not result in significant clusters of activation. Also the ROI analysis investigating differences between inequality conditions did not yield sex differences.

Supplementary analysis

Punishment of the excluders in the Dictator Game: time effects

To investigate whether punishment frequency progressively declined during the Dictator Game, we tested whether punishment frequency was lower in the second and third run of the experiment (each run lasted 7.7 minutes). First, a repeated measures ANOVA was performed with 'Inequality condition' (5 levels: beneficial inequality, non-costly mild inequality, non-costly severe inequality, costly inequality and prosocial inequality), 'Recipient' (2 levels: includers vs. excluders) and 'Run' (3 levels: Run 1, 2 and 3) as within-subjects factors and the percentage of unequal offers as the dependent variable. This analysis resulted in a main effect of 'Run', $F(2, 50) = 6.56, p < .01, \eta_p^2 = .21$ and significant interaction effects of 'Run x Inequality condition', $F(8,200) = 2.52, p < .05, \eta_p^2 = .09$ and 'Run x Inequality condition x Recipient', $F(8,200) = 3.53, p < .01, \eta_p^2 = .12$.

To further investigate these interaction effects, we ran two follow-up repeated measures ANOVAs for each recipient separately with 'Inequality condition' (5 levels) and 'Run' (3 levels) as within-subjects factors and the percentage of unequal offers as the dependent variable. For the includers, there was no main effect 'Run' ($p = .276$) and no significant 'Run x Inequality condition' ($p = .173$). For the excluders this analysis yielded both a main effect of 'Run', $F(2, 50) = 6.60, p < .01, \eta_p^2 = .21$ and a significant interaction effect of 'Run x Inequality condition', $F(8,200) = 3.82, p < .005, \eta_p^2 = .13$. This effect was driven by the Costly inequality condition, $F(2,50) = 8.72, p < .005, \eta_p^2 = .26$, showing that Costly Inequality for the excluders was chosen more in the first run (37%) compared to the second (18%; $p < .05$) and third run (17%, $p < .05$), in which costly inequality was chosen at similar rates ($p = 1$). There was no significant main effect of 'Run' in the Beneficial Inequality ($p = .766$), Mild non-costly Inequality mild ($p = .054$), Severe non-costly Inequality ($p = .057$) and Prosocial Inequality ($p = .506$) conditions (see supplementary figure 1). Together, these results show that punishment is executed less during the later stages of the experiments when participants have to give up money to punish the excluders.



Supplementary figure 1. Mean percentages of trials on which participants chose an unequal distribution in each run of the Dictator Game (each run consisted of 60 trials and lasted 7.7 minutes) for players who previously included and excluded them during Cyberball (error bars represent standard errors of the mean). Each form of ‘Inequality’ is displayed on the x-axis (red coins for participants; blue coins for the recipients). Unequal distributions were pitted against an equal distribution of money (5 coins for the participant / 5 coins for the recipient). BI = Beneficial Inequality; NCI = Non-costly Inequality; CI = Costly Inequality; PI = Prosocial Inequality