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REGULAR ARTICLE

Functional neural substrates of football fanaticism: Different pattern of brain responses and connectivity in fanatics

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Aim: Sports activities provide social interaction for humans. Commitment to a given team is a salient feature of being a sports fan and becomes a prominent part of self-identification for fanatics. Emotion, subjective hedonic experience, and non-romantic love are related to fan behaviors. Few studies have evaluated the neural basis of sports fanaticism.

Methods: Thirty men, including 16 football fanatics and 14 non-fanatics, with a mean age of 27.4 ± 6.4 years (range, 20–48 years) were enrolled. Subjects underwent functional MRI while watching a set of goals scored by favorite, rival, and neutral teams.

Results: The analysis of variance in a general linear model revealed a significant Group × Condition interaction effect in the bilateral dorsal anterior cingulate cortex (dACC) that was more prominent in the left hemisphere. In the post-hoc comparisons, fanatics showed increased activation in bilateral dACC, supplementary motor area, superior frontal cortex, right dorsolateral prefrontal cortex, and right insula for Favorite > Neutral contrast and an increased activation in bilateral dACC and supplementary motor area for Rival > Neutral contrast. Seed-based connectivity analyses using the areas with significant activation differences revealed increased connectivity between dACC and several regions, including the left posterior lateral temporal area, insula, bilateral medial temporal area, and medial superior frontal area as well as the basal ganglia in fanatics compared to non-fanatics.

Conclusion: Our results suggest that football fanatics exhibit a different brain activation and connectivity pattern from non-fanatics, both under favorable and unfavorable conditions. This brain activity and connectivity pattern under emotionally laden conditions may represent higher responses to rewards, higher emotional valence attribution, and stronger motivational state of football fanatics, which might underlie their unusual behavioral responses.

Keywords: *anterior cingulate cortex, fanaticism, functional neuroimaging.*

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One of the defining features of the modern human being is its capacity to engage in advanced social interactions, including social affiliations.[1] One popular mode of social interaction is sporting activities. Football is one of the most popular team sports in the world. Commitment to a given team is a salient feature of being a sports fan and the performance of 'the team' often influences the emotional state of the fans depending on the level of devotion.[2, 3]

There are several classification systems for sports fans based on their levels of devotion. Hunt and coworkers grouped sports fans as 'temporary fan,' 'local fan,' 'devoted fan,' 'fanatical fan,' and 'dysfunctional fan.'[4] In the case of fanatical and dysfunctional fans, commitment to a favorite team becomes a prominent part of their social identity. Another important determinant factor for fanatics is having an opponent, a 'rival team,' which introduces an in-group/out-group bias in their social life. On the other hand, it was proposed that a feeling of belongingness and passion for a football team could be considered as a form of non-romantic love called 'tribal love.'[5]

The reward circuit, comprising several cortical and subcortical areas, was found to be the shared activation region in different types of emotional bonding (such as romantic love and maternal love) and is co-activated in addition to areas specific to each type of bonding.[6] In the reward circuit, the reward value of the reinforcer is presumed to be processed in anterior parts of the orbitofrontal cortex, an epicenter for emotional processing and hedonic experience.[7] Reward values are then utilized to affect behavior, learning, and memory as well as providing subjective hedonic experience. The orbitofrontal cortex has dense reciprocal connections with the anterior cingulate cortex (ACC) and amygdala.[8] The ACC network, which has subcortical components, such as the nucleus accumbens, ventral pallidum, and mediodorsal thalamic nucleus, is modulated by dopaminergic input from the ventral tegmental area.[9, 10]

We hypothesized that strongly devoted football fanatics may show a different pattern of activation to emotional stimuli in the reward circuit compared to non-fanatics. We aimed to test this hypothesis using functional magnetic resonance imaging (fMRI) by assessing neural responses to emotionally laden stimuli with positive and negative valence.

Methods

Subjects

Thirty healthy male volunteers (16 football fans and 14 non-fanatic football spectators, mean age 27.4 ± 6.4 years, range 20–48 years)

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were included in the study. Exclusion criteria were any sensory deficits, history of major neuropsychiatric disorders, and history of substance abuse except for tobacco use in the last month. The Sport Spectator Identification Scale (SSIS) was used for quantifying the degree of fanaticism.[11] The validated Turkish version[12] was administered to all volunteers to measure their level of identification with the Fenerbahçe Sports Club, which is one of the most popular football teams in Turkey. Categorization by Hunt and coworkers[4] was used to classify fans into one of the five groups based on their level of dedication: temporary, local, devoted, fanatical, and dysfunctional. We then divided the group into fanatic and non-fanatic subjects. Subjects in the two strongest fanaticism categories (i.e., dysfunctionals and fanaticals) were combined and named the 'fanatics group,' and subjects in the weakest fanaticism category (i.e., temporary supporters) were named the 'non-fanatics group'; those in the two remaining categories (i.e., local fans and devoted fans) were excluded from the study.

Informed consent

The procedure was approved by the local Ethics Committee of Istanbul University, Istanbul Faculty of Medicine. Informed consent was obtained from all individual participants included in the study.

Experimental paradigm

During the fMRI task, subjects viewed 15 consecutive videos. They were 25 s long and each presented a goal-scoring moment, with 10-s rest intervals between them (Fig. 1). The videos were divided into three blocks, each including five consecutive videos. These were (i) five goals scored by the favorite team (Fenerbahçe) from the National Football League against the main rival team (Galatasaray) in a historical match in which the favorite team won 6–0 (Fav condition); (ii) five goals scored by the rival team (Galatasaray) against the favorite team (Fenerbahçe) in another historical match in which the rival team won 5–1 (Riv condition); and (iii) five goals scored by a team in a national league match in the Australian A-League with a score of 5–0 (Neut condition). For neutrality and unfamiliarity, a match from the Australian soccer league (A-League) was chosen because the A-League is not popular in Turkey and no national TV channels broadcast A-League matches. Also, the selected A-league teams had different team colors to those of the favorite and rival teams to minimize the similarity effect. After the MRI scan, participants were asked if they remembered the particular match of the goals presented to them. All of them remembered the two matches involving their devoted team and the rival team. None of them declared that they knew the A-League teams, or that they remembered the A-League match presented to them as a neutral match.

All participants watched all 15 goals in order to avoid any confounding effects of familiarity. The five goals each for the favorite, rival, and neutral teams were presented consecutively in three separate blocks to obtain more stable affective responses by maintaining the general context of each match. In order to exclude the priority effect, the sequence of the Fav, Neut, and Riv matches was shown to half of the participants in each group, whereas the other half watched the sequence of Riv, Neut, and Fav. Total duration of the experiment was 8 min 55 s for each subject.

MRI acquisition

Structural and EPI images were acquired on a Philips 3-Tesla MRI system equipped with a SENSE-32 channel head coil (Philips Achieva, Best, The Netherlands). High-resolution T1-weighted structural images were collected with 250-mm field of view, 160 slices, 1-mm slice thickness, and 0-mm gap.

Functional MRI data were obtained by using an echo-planar imaging sequence with the following parameters: repetition time = 2 s, echo time = 30 ms, flip angle = 90, field of view = 224 mm × 240 mm, acquisition matrix size = 112 × 117, 4-mm slice thickness, 0-mm gap, voxel size = 2 × 2 × 4 mm^3 in-plane resolution. Each volume contained 36 axial slices covering the whole brain, and whole fMRI session consisted of 268 volumes following 10 dummy volumes, with a total scan time of 9 min 16 s.

Data processing

Preprocessing

Image preprocessing was carried out using the statistical parametric mapping software package (SPM12; http://www.fil.ion.ucl.ac.uk/spm). For each participant, functional images were first realigned to the first scan to correct head motion. Only participants with head motion less than ±2 mm in the x, y, or z direction and less than ±2° rotation in each axis were included. The corrected images were then spatially normalized to the Montreal Neurological Institute template in SPM12 and re-sampled to 2-mm^3 voxels. Finally, the functional images were spatially smoothed by convolution with an isotropic Gaussian kernel (full-width half maximum = 8 mm).

General linear model analyses

The first-level analysis was performed using a general linear model (GLM) as implemented in SPM12. For each subject, three temporal regressors were specified, each one consisting of a boxcar time series convolved with a canonical hemodynamic response function. The regressors represented the time courses of the Fav, Riv, and Neut conditions. The residual effects of head motion were modeled as covariates of no interest in the analysis by including the six head-motion parameters estimated during the realignment stage of the preprocessing. The high-pass filter cut-off was 128 s.

In order to determine significant activations, a full-factorial 2 × 3 analysis of variance (ANOVA) with Group (two levels: fanatics and non-fanatics) as between-subject factor and Condition (three levels: Fav, Riv, Neut) as within-subject factor was computed using a random-effects model. First, Group × Condition interaction was calculated. Subsequently, in order to explore the nature of this interaction, post-hoc analyses were performed. For the interaction and post-hoc effects, a cluster-forming threshold was set at $P < 0.005$. Cluster-level significance was set at family-wise error (FWE)-corrected $P < 0.05$ for the interaction effect, and FWE-corrected $P < 0.017$ for the post-hoc analyses adjusted by Bonferroni method for multiple comparisons (Fav vs Neut, Riv vs Neut, Fav vs Riv). Additionally, to

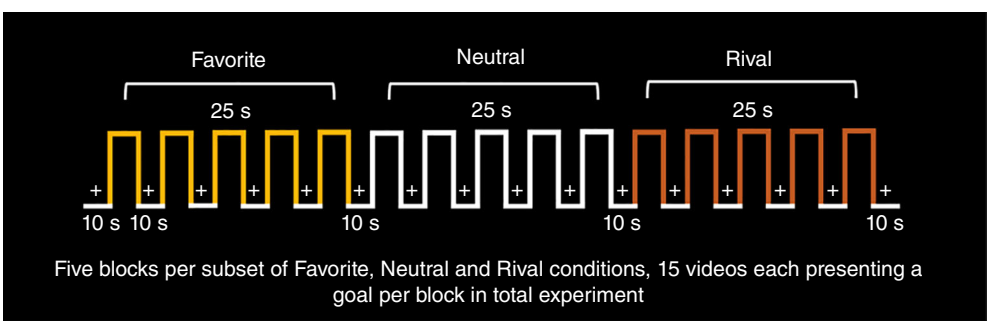


Fig. 1 Functional MRI paradigm. 'Favorite' corresponds to videos of goals scored by the favorite team in a past match against the rival team, while 'Rival' corresponds to the opposite condition. 'Neutral' corresponds to videos of goals scored in a match in another country. The order of the 'Favorite' versus 'Rival' conditions was reversed in half of the subjects to eliminate priority effect.

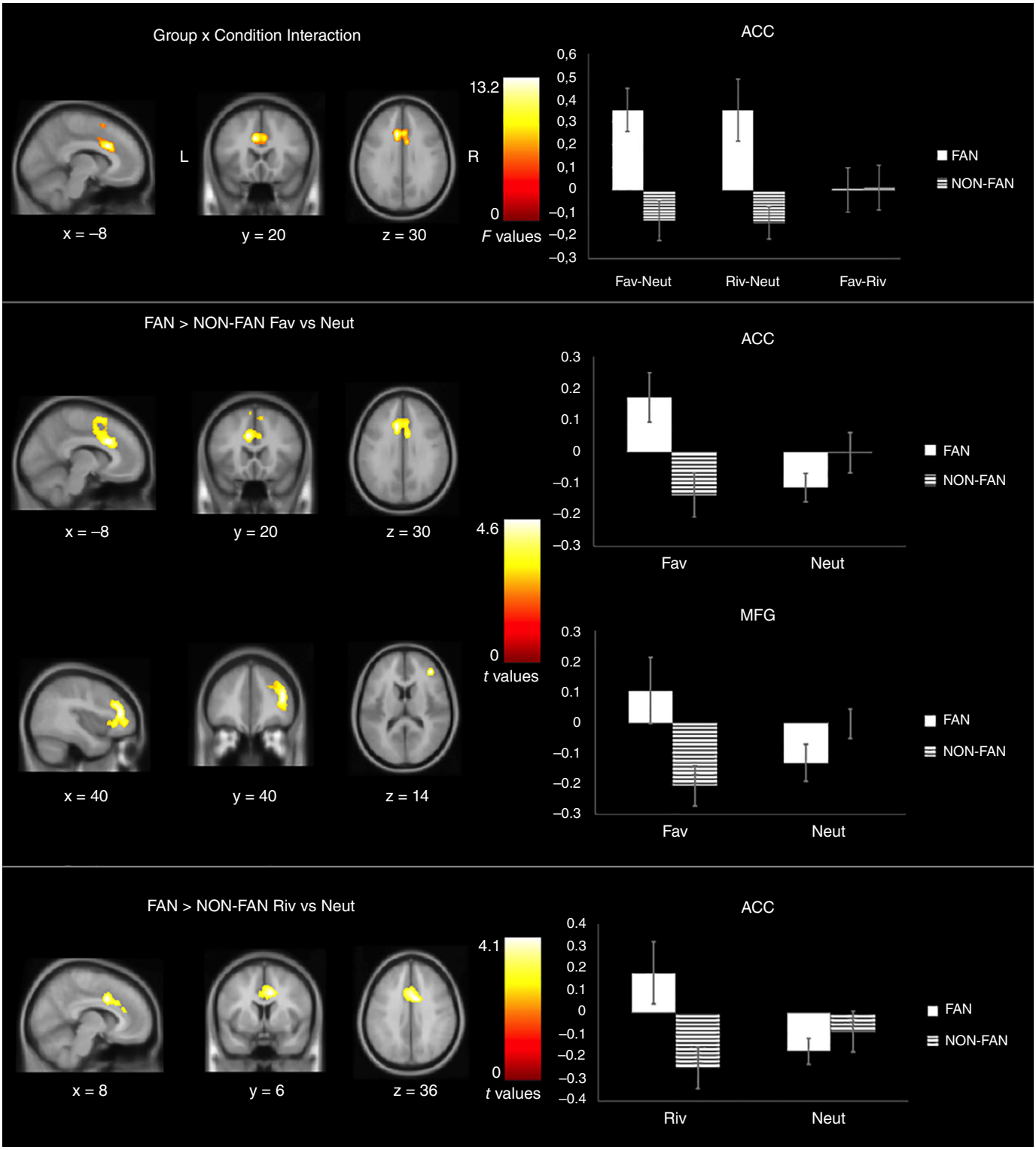


Fig. 2 (Top) Analysis of variance revealed a significant Group × Condition interaction effect in the bilateral dorsal anterior cingulate cortex (dACC; 948 voxels, peak coordinates: –8, 20, 30, $F = 13.16$, $P_{FWE\text{-}corr} = 0.003$), centered on the left dACC. (Middle) Fanatics (FAN) compared to non-fanatics (NON-FAN) showed increased activation at a cluster of 2034 voxels (peak coordinates: –8, 20, 30, $T_{max} = 4.62$, $P_{FWE\text{-}corr} < 0.001$), including bilateral (more prominently left-sided) dACC, bilateral supplementary motor area (SMA), bilateral superior frontal gyrus (SFG), and at a cluster of 1069 voxels (peak coordinates: 40, 40, 14, $T_{max} = 4.57$, $P_{FWE\text{-}corr} = 0.011$) centered on the right middle frontal gyrus (MFG), comprising right dorsolateral prefrontal cortex areas for the favorite (Fav) vs neutral (Neut) contrast. (Bottom) The FAN revealed increased activation in bilateral dACC (more prominently in the right side), and bilateral SMA (1127 voxels, peak coordinates: 8, 6, 36, $T_{max} = 4.09$, $P_{FWE\text{-}corr} = 0.008$) compared to the NON-FAN for the rival (Riv) vs Neut contrast. The results are superimposed on the MNI-152-T1 (2-mm) standard image. Bar graphs in the right column indicate group-averaged beta values extracted from 1st level contrasts while error bars represent standard error (cluster-forming threshold $P < 0.005$, combined with cluster-level FWE-corrected $P_{FWE\text{-}corr} < 0.05$ for interaction effect and cluster-forming threshold $P < 0.005$, combined with cluster-level family-wise error (FWE)-corrected $P_{FWE\text{-}corr} < 0.017$ with Bonferroni adjustment for post-hoc comparisons). ACC, anterior cingulate cortex.

further determine the nature of both interaction and post-hoc effects (i.e., whether the clusters showing interaction effect between Group and Conditions and other clusters observed in post-hoc comparisons were driven by greater activation in the fanatics group), the resulting clusters were defined as regions of interest. Average beta values for each ROI were extracted from first-level contrasts (Fav, Riv, and Neut) of each subject using MarsBaR (http://marsbar.sourceforge.net) and then illustrated with bar graphs by averaging for the fanatic and non-fanatic groups (Fig. 2).

We focused on between-group differences in order to avoid any confounding effects due to differences in familiarity of the subjects for the matches from the national league versus that from another country's league. Consequently, we did not calculate the main effects.

Connectivity analysis

Functional connectivity analyses were carried out using the CONN-fMRI functional connectivity toolbox Ver. 17 (www.nitrc.org/projects/conn). In order to remove potential sources of noise, the BOLD signal was bandpass filtered between 0.01 and 0.1 Hz. Additionally, the effects of the Fav, Riv, and Neut conditions, white matter, and cerebrospinal fluid (CSF) components and the six head-motion parameters derived from spatial motion correction were added as confounds in the denoising step of the CONN toolbox.

Seed-to-voxel functional connectivity maps of the whole brain were created for each participant. The areas with significant activation differences (ACC and middle frontal gyrus [MFG] observed in the post-hoc comparison of Fav vs Neut for Fanatics > Non-fanatics and ACC seen in the post-hoc comparison of Riv vs Neut for Fanatics > Non-fanatics) were defined as source ROI. Bivariate correlation coefficients were computed between the time course of each source and the time course of all other brain voxels. All correlation maps were subsequently transformed to normal distribution by Fisher's z transformation.

Individual seed-to-voxel maps were entered into a second-level analysis. We performed group comparison only for the Fav vs Neut and Riv vs Neut contrasts by using the specific seeds that were created regarding the activation area for the corresponding GLM contrast. A cluster-forming threshold of $P < 0.005$ was used with a cluster-level significance set at FWE-corrected $P < 0.05$.

Correlation analysis

Correlation analysis between fanaticism scores (SSIS) and the significant activations in GLM (average beta values for each significant cluster) was carried out in the fanatic group using SPSS Ver. 21.0 (IBM, Armonk, NY, USA).

Results

Two of the fanatic volunteers were excluded from the study, one due to substance use just before MRI acquisition and the other due to severe anxiety during scanning, resulting in a total population of 28 subjects (14 in the fanatics group and 14 in the non-fanatics group). The mean age of the two groups was similar (31.07 ± 10.39 years for fanatics and 27.51 ± 8.78 years for non-fanatics, $P = 0.33$). There was a significant difference in the mean SSIS scores between the fanatics (52.2 ± 3.1) and non-fanatics (7.3 ± 0.7; $P = 0.0001$).

Activation differences

The 2×3 ANOVA revealed a significant interaction between Group and Condition in the bilateral dACC that was more prominent on the left side (948 voxels, peak coordinates: −8, 20, 30 [left cingulate sulcus], $F = 13.16$, $P_{FWE\text{-}corr} = 0.003$, $\eta^2 = 0.252$; cluster-forming threshold $P < 0.005$ combined with cluster-level FWE-corrected $P_{FWE\text{-}corr} < 0.05$). Post-hoc comparisons between the two groups showed a statistically significant activation difference both for the Fav vs Neut and Riv vs Neut contrast, while no significant activation difference was found for the Fav vs Riv contrast. For the Fav-versus-Neut contrast, the fanatics showed increased activation at two clusters compared to the non-fanatics: a cluster of 2034 voxels (peak coordinates: −8, 20, 30 [left cingulate sulcus], $T_{max} = 4.62$, $P_{FWE\text{-}corr} < 0.001$, $d = 1.05$), including the bilateral dACC (more prominent in the left side), supplementary motor area (SMA), and superior frontal gyrus (SFG), and a cluster of 1069 voxels (peak coordinates: 40, 40, 14 [right middle frontal gyrus], $T_{max} = 4.57$, $P_{FWE\text{-}corr} = 0.011$, $d = 1.03$), centered on the right MFG, including the inferior frontal gyrus (IFG), extending into the SFG and insula. For the Riv vs Neut contrast, the fanatics showed increased activation as compared to non-fanatics: a cluster of 1127 voxels (peak coordinates: 8, 6, 36 [right cingulate sulcus], $T_{max} = 4.09$, $P_{FWE\text{-}corr} = 0.008$, $d = 0.93$), bilateral dACC (more prominent in the right side) extending into the bilateral SMA (cluster-forming threshold $P < 0.005$ combined with cluster-level FWE-corrected $P_{FWE\text{-}corr} < 0.017$ with Bonferroni adjustment; Fig. 2, Table 1).

Connectivity analyses

The cluster including mainly dACC (ACC seed-1) and the cluster including mainly MFG (MFG seed), which were specific to the Fav vs Neut contrast in which fanatic supporters showed increased activation compared to non-fanatic supporters, were used as source ROI for the Fav vs Neut contrast. The ACC seed-1 showed increased connectivity with two clusters in fanatics compared to non-fanatics for the Fav > Neut contrast (cluster-forming threshold $P < 0.005$ combined with cluster-level FWE-corrected $P_{FWE\text{-}corr} < 0.05$). The first one included the left middle temporal gyrus (MTG) and inferior temporal gyrus (ITG; 1023 voxels, peak coordinates: −66, −50, −8 [left posterior MTG], $t = 6.76$, $P_{FWE\text{-}corr} = 0.0003$, $d = 2.65$) and the second included the posterior parahippocampal gyrus (PHG), hippocampus, and posterior fusiform gyrus (FusG; 999 voxels, peak coordinates: −14, −8, −14 [left hippocampus], $t = 5.37$, $P_{FWE\text{-}corr} = 0.0004$, $d = 2.11$; Table 2 and Fig. 3). The MFG seed did not show any significant connectivity differences between the two groups for the Fav vs Neut contrast.

Table 1. Full factorial 2×3 ANOVA results of the activation analysis

Comparison	Regions showing significant activation	Size (voxel)	MNI Peak coordinates	F_{max}/T_{max}	$P_{FWE\text{-}corr}$
Group × Condition interaction	Bilateral dACC	948	–8, 20, 30	13.16	0.003
Fav vs Neut	Bilateral dACC, bilateral SMA, and SFG	2034	–8, 20, 30	4.62	<0.001†
Fav vs Neut	Right MFG, IFG, SFG, and insula	1069	40, 40, 14	4.57	0.011†
Riv vs Neut	Bilateral dACC and SMA	1127	8, 6, 36	4.09	0.008†

†Fanatics > Non-fanatics comparison.
dACC, dorsal anterior cingulate cortex; Fav, favorite; FWE, family-wise error; IFG, inferior frontal gyrus; MFG, middle frontal gyrus; MNI, Montreal Neurological Institute; Neut, neutral; Riv, rival; SFG, superior frontal gyrus; SMA, supplementary motor area.

Table 2. Seed-to-voxel whole brain connectivity analysis for the ACC seed-1 for the Fav > Neut contrast and for the ACC seed-2 for the Riv > Neut contrast

Comparison	Regions showing significant connectivity	Size (voxel)	MNI Peak coordinates	T_{max}	$P_{FWE\text{-}corr}$ †
Fav > Neut	Left MTG and ITG	1023	−66, –50, –8	6.76	0.0003
	Left PHG, HC and FusG	999	–14, –8, –14	5.37	0.0004
Riv > Neut	Left MTG, STG, ITG and FusG	1527	−44, –50, –12	5.06	0.00001
	Left FusG and culmen	460	−22, –32, –22	4.12	0.045
	Bilateral medial SFC	913	12, 68, 22	4.96	0.001
	Left putamen, insula, PHG, caudate and amygdala	1308	−34, –4, 0	5.12	0.00005
	Right putamen, PHG and amygdala	491	28, 8, –6	4.92	0.034

†Fanatics > Non-fanatics comparison.

ACC, anterior cingulate cortex; Fav, Favorite; FusG, fusiform gyrus; FWE, family-wise error; HC, hippocampus; ITG, inferior temporal gyrus; MNI, Montreal Neurological Institute; MTG, middle temporal gyrus; Neut, Neutral; PHG, parahippocampal gyrus; Riv, rival; STG, superior temporal gyrus; SFC, superior frontal cortex.

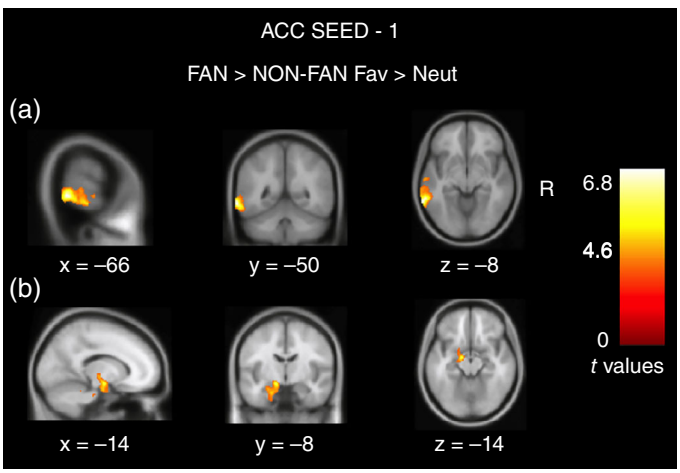


Fig. 3 Increased functional connectivity of the anterior cingulate cortex (ACC) seed-1 with (a) left middle temporal gyrus (MTG) and inferior temporal gyrus (ITG; 1023 voxels, peak coordinates: –66, –50, –8, t = 6.76, $P_{FWE\text{-}corr}$ = 0.0003) and (b) the left parahippocampal gyrus (PHG), hippocampus (HC), and fusiform gyrus (FusG; 999 voxels, peak coordinates: –14, –8, –14, t = 5.37, $P_{FWE\text{-}corr}$ = 0.0004) in fanatics (FAN) compared to non-fanatics (NON-FAN) for Favorite (Fav) > Neutral (Neut) contrast (cluster-forming threshold P < 0.005, combined with cluster-level family-wise error (FWE)-corrected $P_{FWE\text{-}corr}$ < 0.05). The results are superimposed on the MNI-152-T1 (2-mm) standard image.

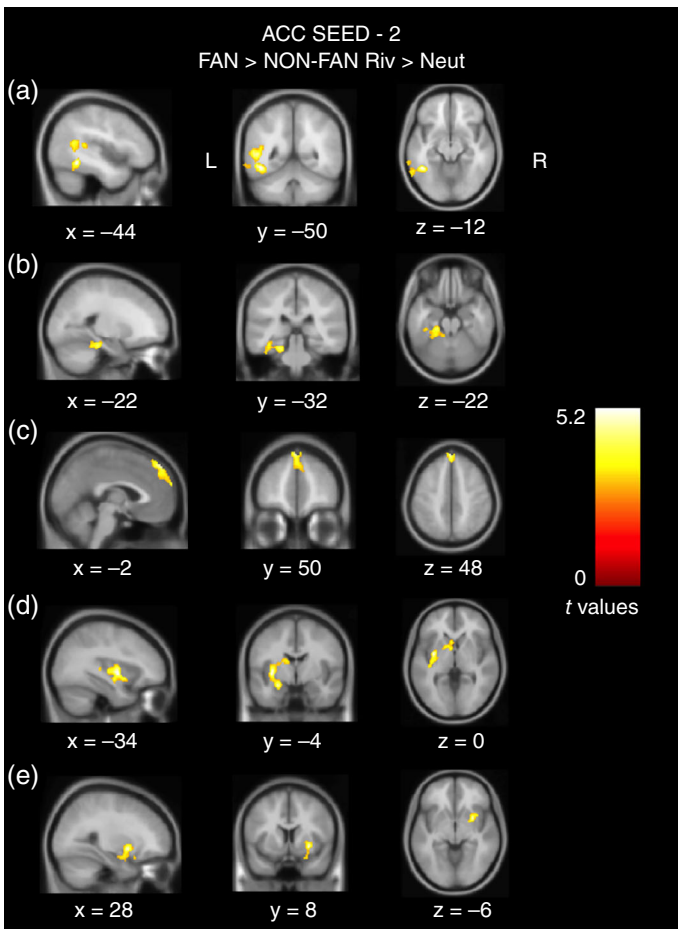


Fig. 4 Increased functional connectivity of the anterior cingulate cortex (ACC) seed-2 with (a) left middle temporal gyrus (MTG), inferior temporal gyrus (ITG), superior temporal gyrus (STG), and fusiform gyrus (FusG; 1527 voxels, peak coordinates: –44, –50, –12, t = 5.06, $P_{FWE\text{-}corr}$ = 0.00001); (b) left FusG and culmen (460 voxels, peak coordinates: –22, –32, –22, t = 4.12, $P_{FWE\text{-}corr}$ = 0.045); (c) bilateral medial superior frontal cortex (SFC; 913 voxels, peak coordinates: 12, 68, 22, t = 4.96, $P_{FWE\text{-}corr}$ = 0.001); (d) left putamen, insula, parahippocampal gyrus (PHG), caudate, and amygdala (1308 voxels, peak coordinates: –34, –4, 0, t = 5.12, $P_{FWE\text{-}corr}$ = 0.00005); and (e) right putamen, PHG, and amygdala (491 voxels, peak coordinates: 28, 8, –6, t = 4.92, $P_{FWE\text{-}corr}$ = 0.034) in fanatics (FAN) compared to non-fanatics (NON-FAN) for Rival (Riv) > Neutral (Neut) contrast (cluster-forming threshold P < 0.001, combined with cluster-level family-wise error (FWE)-corrected $P_{FWE\text{-}corr}$ < 0.05). The results are superimposed on the MNI-152-T1 (2-mm) standard image.

The cluster including mainly dACC (ACC seed-2), which was specific to the Riv vs Neut contrast in which fanatic supporters showed increased activation compared to the non-fanatic supporters, was used as the source ROI for the Riv-versus-Neut contrast. ACC seed-2 showed increased connectivity with five clusters in fanatics compared to non-fanatics for the Riv > Neut contrast (cluster-forming threshold P < 0.005 combined with cluster-level FWE-corrected $P_{FWE\text{-}corr}$ < 0.05). The first one was located at the left lateral temporal region, including MTG, STG, ITG, and FusG (1527 voxels, peak coordinates: −44, –50, –12 [left ITG], t = 5.06, $P_{FWE\text{-}corr}$ = 0.00001, d = 1.98). The second included the left FusG and culmen (460 voxels, peak coordinates: −22, –32, –22 [left FusG], t = 4.12, $P_{FWE\text{-}corr}$ = 0.045, d = 1.62). The third cluster included the bilateral medial superior frontal cortex (913 voxels, peak coordinates: 12, 68, 22 [right medial superior frontal cortex], t = 4.96, $P_{FWE\text{-}corr}$ = 0.001, d = 1.95). The fourth cluster included the left putamen, insula, PHG, caudate, and amygdala (1308 voxels, peak coordinates: −34, –4, 0, t = 5.12, $P_{FWE\text{-}corr}$ = 0.00005, d = 2.01) and lastly the fifth cluster included the

right putamen, PHG, and amygdala (491 voxels, peak coordinates: 28, 8, –6, $t = 4.92$, $P_{FWE\text{-}corr} = 0.034$, $d = 1.93$; Table 2 and Fig. 4).

Correlation analyses

Spearman's correlation was run in the fanatic group to assess the relation between the SSIS scores and the significant activations in GLM (average beta values for each significant cluster). There was a positive correlation between the Fav > Neut contrast (average beta values for the ACC cluster obtained from the Group × Condition interaction) and SSIS scores ($r_s = 0.588$, $P = 0.13$ [1-tailed]) and between the Fav condition (average beta values for the ACC cluster obtained from the Fav vs Neut contrast in the post-hoc analysis) and SSIS scores ($r_s = 0.499$, $P = 0.35$ [1-tailed]).

Discussion

Our results revealed that devoted football fanatics exhibit a different pattern of brain activation and connectivity as compared to non-fanatics while experiencing a favorable or unfavorable outcome of their team in comparison to a 'neutral' condition. The main finding was increased recruitment of the dACC (corresponding to the 'mid-cingulate cortex', the term recently proposed to describe this distinct area), during both positive and negative experiences associated with their team in fanatics as compared to non-fanatics. In addition, as positively correlated with an individual's fanaticism level, viewing the success of the favorite team elicited dACC activation that was more pronounced on the left side, with an additional activation on the right dorsolateral prefrontal cortex as compared to viewing the success of the rival team, which elicited activation in the posterior part of the dACC and was more pronounced on the right side regardless of the individual's fanaticism level. Functional connectivity analyses yielded increased connectivity of the dACC with the left posterior lateral temporal and left posterior medial temporal areas during a favorable condition, and a more widespread connectivity with the brain regions including the left insula and left posterior lateral temporal area as well as bilateral medial temporal, bilateral medial superior frontal areas, and bilateral basal ganglia during the opposite condition. The MFG seed, however, did not show any significant connectivity differences.

In order to avoid confounding effects, such as familiarity with the specific football events, two well-known matches between the favorite and rival teams were selected, and both fanatic and non-fanatic subjects confirmed that they had seen these specific matches before. In addition, a neutral match was selected from a foreign league that is not broadcasted in Turkey and it was verified that none of the subjects had seen this match previously. Nevertheless, a difference in familiarity with the matches from the national versus a foreign league cannot be excluded with certainty, which may be a potential confounding factor. The difference in familiarity, however, is equally likely for both fanatic and non-fanatic subjects; we therefore assume that the between-group differences are not caused through familiarity effects.

The ACC, as regards the main finding in this study, has been attributed to both affective and cognitive functions, such as assigning emotional valence to internal and external stimuli, motivation, modulation of emotional responses, processing of pain, error monitoring, response selection, and execution of movements.[13] Recently both dorsal and ventral ACC have been implicated as the major hub for the 'empathy circuit' and 'core self network.'[14–16] The ACC also participates in the reward circuit with functional specializations: ventral ACC activity correlates with the expected value of options, whereas action–selection activates dorsal ACC. Cognitive functions of the ACC, which are generally subsumed under the term 'cognitive control,' can be listed as conflict-monitoring, approach–avoidance decisions, willed control of actions, and emotional appraisal.[17] The ACC is also associated with affective behaviors and psychiatric morbidities. Electrical stimulation of the ACC was shown to induce emotional responses, such as fear, pleasure, euphoria, sense of well-being, and agitation.[13] Lesions in the ACC were associated with various affective changes, including apathy, depression, obsessions, disinhibition, and hypersexuality. In a study using resting-state fMRI, impulsivity, which is a common feature in fanatics, was linked to functional connectivity of ACC.[18]

In our study, both favorable (positive emotions) and opposite (negative emotions) conditions were associated with significant activation of the dACC. This may be related to the emotional valance and emotional awareness of both conditions compared to the neutral condition (no or less emotions) as the ACC plays a critical role in assigning emotional valance to all kinds of stimuli. This assumption is supported by regional cerebral blood flow studies showing a positive correlation between emotional awareness (as measured by a scale) and activity in the dACC while viewing emotional films or pictures, but only when the emotional stimuli were highly physiologically arousing.[17, 19, 20] The increased activity in the ACC, dorsolateral prefrontal cortex, and insula in our study may also be related to invoking emotional memories from the past (since all goals were from previous matches), as it was also shown that remembering emotional events was associated with activation in the ACC, insula, and prefrontal cortex.[21] According to Keenan and coworkers, the right dorsolateral prefrontal cortex is likely to be involved in the memory of information that is personally meaningful.[22] This may explain the co-activation of the right MFG, SFG, and IFG in addition to the dACC in our study. Lateralization of activity in the dACC observed predominantly on the left side during the favorable condition and on the right side during the opposite condition may be explained as follows: There is evidence for lateralized autonomic regulation by the cingulo-opercular network, parasympathetic activity regulated by the left and sympathetic activity by the right side,[23] associating parasympathetic-dominant relaxed, pleasant feelings with left-sided activity and sympathetic-dominant angry, unpleasant feelings with right-sided activity.

The ACC has also been shown to play a critical role in various social interactions and attachment behaviors, including maternal–infant interaction, romantic love, and social categorization.[6, 13] Supporting a sports team fanatically and extreme disliking of a rival team are examples of attachment and detachment behaviors. These behaviors are strongly associated with the brain's reward circuit, including the ACC, limbic structures, and insula. Involvement of these areas may constitute a link to the evolution of human social behavior: Cikara and coworkers suggest that 'evolutionarily old neural systems, which may have developed to respond to physically rewarding and painful stimuli in the service of reinforcing adaptive behaviors, have evolved to encode group-level rewards and punishments.'[24]

While various functions can be associated with activations of these brain areas, from a network approach, they are also part of distinct intrinsic connectivity networks. Functional connectivity MRI studies revealed that MFG and IFG comprise the anterior portion of the central executive network (CEN; also called the 'frontoparietal network'), while the dACC is the major dorsal hub for the salience network (SN). The SN, which also includes other distinct limbic areas, is thought to identify the most relevant among several internal and external stimuli in order to guide behavior.[25] Converging evidence from a number of neuroimaging studies suggests that the SN responds to the degree of subjective salience, whether cognitive, homeostatic, or emotional.[26] Menon suggests that the SN contributes to a variety of complex brain functions, including communication, social behavior, and self-awareness, through integration of sensory, emotional, and cognitive information.[27] He also suggests that in the SN, events that are likely to be perceived as salient include stimuli that are pleasurable and rewarding, self-relevant, or emotionally engaging. It is apparent that all these emotions correspond to feelings of a football fanatic while watching and remembering a memorable past victory.

A study by Stevens and coworkers revealed a positive correlation between emotional awareness and activity in the dACC and suggested that greater activation of this area in individuals with higher emotional awareness might indicate greater deployment of attentional

resources to emotional processing.[17] According to a model proposed by Bressler and Menon, the SN acts as a dynamic switch between the default mode network (DMN) and the CEN: When the demand is for an endogenously mediated, self-referential mental activity, the SN engages the DMN and suppresses the external irrelevant stimuli. In contrast, when the demand is for an exogenously driven, cognitively demanding mental activity, the SN recruits the CEN in order to manipulate information in working memory while suppressing the DMN to keep attention focused on task-relevant activities.[28] Co-activation of areas involved in the SN and CEN in our study is in accordance with the second condition: It is likely that the salience value attributed by the SN to the scenes involving the favorite team's goals recruits the CEN in order to maintain what is viewed in the working memory.

While the role of activated areas are discussed with a functional and network perspective above, our task-based functional connectivity analyses further revealed connectivity changes between the dACC and a set of temporal lobe structures. In the fanatic group, the favorable condition was found to be associated with increased functional connectivity between the dACC and left MTG, ITG, pMTG, posterior parahippocampal cortex, and posterior temporal fusiform cortex. The majority of these regions are part of the DMN, semantic control network, and visual network. Hyperconnectivity between the dACC and DMN areas may represent the neural correlate of heightened emotional valence attributed by the fanatics to their object of choice (i.e., their favorite team). These connectivity differences in emotional networks may underlie the abnormal emotional processing and may be associated with hyperemotional behaviors seen in fanatics. The ITG is a component of the ventral visual association cortex that carries information related to object- and face-recognition to the hippocampus. It feeds to the perirhinal cortex and then to the posterior EC (BA28), which also receives spatial information from the posterior parahippocampal gyrus, where both spatial and object-related aspects of experience are integrated and fed into hippocampal formation for later recollection.[29, 30] No direct connection exists between the dACC and ITG. Nevertheless, both areas can be considered to feed mnestic information to the SN. Hence, football fanatics may have enriched neural circuits feeding emotional–memory contents into their SN.

Another explanation for connectivity patterns observed in our study may be the different responses of the brain due to the recognition of different types of stimuli. The dACC may be in a critical position in modulating the recognition of stimulus type. In our study, the unfavorable condition elicited more widespread couplings between the ACC and regions mainly found in the favorable condition in conjunction with right medial temporal structures, bilateral putamen, and left insula. Different couplings may be related to the modulating effect of the dACC, leading to higher involvement of limbic structures and additional participation of insula and basal ganglia structures and the medial superior frontal cortex for the recognition of stimuli with negative emotional valance. In an fMRI study comparing betting versus watching conditions, the betting condition including stimuli with reward-value elicited an increased connectivity between the insula and parahippocampal, lingual, and occipital gyrus. This finding was thought to be an indicator of higher engagement of stimulus recognition and the perceptual saliency process for the stimuli associated with reward, and the insula was proposed as a modulator region in recognition of stimuli with or without reward value.[31] Similarly, in conditions with negative and positive emotional valance as in our study design, the dACC may play the critical modulating role of the insula for the recognition of the different types of stimuli that are emotionally laden rather than carrying a reward value.

In a recent neuroimaging study, Duarte *et al*. analyzed football fans' reactions to winning and losing moments of their favorite team.[5] They found significant activations in the inferior temporal lobe, amygdala, hippocampus, insula, putamen, globus pallidus, thalamus, ventral tegmental area, substantia nigra, and right caudate in the positive versus negative moments, which is similar to the Fav > Riv condition in our study. They also found involvement of the inferior temporal lobe, right parahippocampus, hippocampus, and amygdala bilateral ventral tegmental area and posterior cingulate in the positive versus neutral comparison, which is similar to the Fav > Neut condition in the current study. The discrepancy in the activated areas between the two studies may be related to classifying the fans according to their fanaticism level in our study.

There are several limitations to our study. It has been shown that fanatics, especially dysfunctional ones, frequently have negative personality traits, such as impulsivity, aggressiveness, excitability, and emotional instability. Antisocial personality disorder is also common.[32] We did not perform a detailed psychiatric evaluation to assess presence and severity of psychopathology in our sample. We cannot exclude that altered neural response patterns observed in fanatics may be related to personality traits and psychopathology commonly seen in these subjects. Another limitation of this study is the relatively small sample size. We also did not include any videos containing non-football content as a control. These limitations should be addressed in future studies that attempt to replicate these findings.

In conclusion, our results suggest an alteration in task-related emotional processing associated with altered regional activity and brain connectivity in devoted football fanatics. Altered brain activity and connectivity under emotionally laden conditions may lead to higher response to rewards, higher emotional valence attribution, and stronger motivational state of football fanatics that might underlie their exaggerated behavioral responses. Further studies could assess the relevance of these brain changes with common psychopathologies seen in fanatics who are extremely enthusiastic about and devoted to a sports team. Moreover, neuroimaging studies on all types of fanaticism would be worthwhile to understand the exact role of the ACC in people with extreme devotion and beliefs.

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Disclosure statement

B.B., C.C.M., E.K., C.U-Y., B.S., H.G., T.D., and M.E. declare that they have no conflicts of interest.

Author contributions

B.B., M.E., C.C.M., T.D. conceptualized the study; C.C.M., E.K., C. U-Y., B.S. collected the data; B.B., M.E., T.D., E.K., B.S., H.G. analyzed the data; B.B. wrote the initial draft; H.G., T.D., M.E. edited the manuscript.

REFERENCES

1. Harari YN. *Sapiens: A Brief History of Humankind*. HarperCollins, New York, NY, 2015.
2. Cottingham MD. Interaction ritual theory and sports fans: Emotion, symbols, and solidarity. *Sociol. Sport J.* 2012; **29**: 168–185.
3. Wann DL, Dolan TJ, MeGeorge KK, Allison JA. Relationships between spectator identification and spectators' perceptions of influence, spectators' emotions, and competition outcome. *J. Sport Exerc. Psychol.* 1994; **16**: 347–364.
4. Hunt KA, Bristol T, Bashaw RE. A conceptual approach to classifying sports fans. *J. Serv. Mark.* 1999; **13**: 439–452.
5. Duarte IC, Afonso S, Jorge H, Cayolla R, Ferreira C, Castelo-Branco M. Tribal love: The neural correlates of passionate engagement in football fans. *Soc. Cogn. Affect. Neurosci.* 2017; **12**: 718–728.
6. Bartels A, Zeki S. The neural correlates of maternal and romantic love. *NeuroImage* 2004; **21**: 1155–1166.
7. Kringelbach ML, O'Doherty J, Rolls ET, Andrews C. Activation of the human orbitofrontal cortex to a liquid food stimulus is correlated with its subjective pleasantness. *Cereb. Cortex* 2003; **1991**: 1064–1071.
8. Kringelbach ML. The human orbitofrontal cortex: Linking reward to hedonic experience. *Nat. Rev. Neurosci.* 2005; **6**: 691–702.

9. Olds J, Milner P. Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. *J. Comp. Physiol. Psychol.* 1954; **47**: 419–427.
10. Haber SN. Anatomy and connectivity of the reward circuit. **In:** Dreher J-C, Tremblay L (eds). *Decision Neuroscience: An Integrative Approach*. Academic Press, San Diego, CA, 2017; 3–19.
11. Wann DL, Branscombe NR. Sports fans: Measuring degree of identification with their team. *Int. J. Sport Psychol.* 1993; **24**: 1–17.
12. Gunay N, Tiryaki S. Spor Taraftarı Özdeşleşme Ölçeğinin geçerlik ve güvenirlik çalışması. *Hacettepe Spor Bilimleri Dergisi* 2003; **1**: 14–26.
13. Devinsky O, Morrell MJ, Vogt BA. Contributions of anterior cingulate cortex to behaviour. *Brain J. Neurol.* 1995; **118** (Pt 1: 279–306.
14. Engen HG, Singer T. Empathy circuits. *Curr. Opin. Neurobiol.* 2013; **23**: 275–282.
15. Shamay-Tsoory SG. The neural bases for empathy. *Neurosci. Rev. J.* 2011; **17**: 18–24.
16. Sui J, Gu X. Self as object: Emerging trends in self research. *Trends Neurosci.* 2017; **40**: 643–653.
17. Stevens FL, Hurley RA, Taber KH. Anterior cingulate cortex: Unique role in cognition and emotion. *J. Neuropsychiatry Clin. Neurosci.* 2011; **23**: 121–125.
18. Golchert J, Smallwood J, Jefferies E *et al*. In need of constraint: Understanding the role of the cingulate cortex in the impulsive mind. *NeuroImage* 2017; **146**: 804–813.
19. Lane RD, Reiman EM, Axelrod B, Yun LS, Holmes A, Schwartz GE. Neural correlates of levels of emotional awareness. Evidence of an interaction between emotion and attention in the anterior cingulate cortex. *J. Cogn. Neurosci.* 1998; **10**: 525–535.
20. McRae K, Reiman EM, Fort CL, Chen K, Lane RD. Association between trait emotional awareness and dorsal anterior cingulate activity during emotion is arousal-dependent. *NeuroImage* 2008; **41**: 648–655.
21. Suardi A, Sotgiu I, Costa T, Cauda F, Rusconi M. The neural correlates of happiness: A review of PET and fMRI studies using autobiographical recall methods. *Cogn. Affect Behav. Neurosci.* 2016; **16**: 383–392.
22. Keenan JP, Nelson A, O'Connor M, Pascual-Leone A. Self-recognition and the right hemisphere. *Nature* 2001; **409**: 305.
23. Craig ADB. Forebrain emotional asymmetry: A neuroanatomical basis? *Trends Cogn. Sci.* 2005; **9**: 566–571.
24. Cikara M, Botvinick MM, Fiske ST. Us versus them: Social identity shapes neural responses to intergroup competition and harm. *Psychol. Sci.* 2011; **22**: 306–313.
25. Seeley WW, Menon V, Schatzberg AF *et al*. Dissociable intrinsic connectivity networks for salience processing and executive control. *J. Neurosci.* 2007; **27**: 2349–2356.
26. Menon V, Uddin LQ. Saliency, switching, attention and control: A network model of insula function. *Brain Struct. Funct.* 2010; **214**: 655–667.
27. Menon V. Salience network. **In:** Toga AW (ed.). *Brain Mapping: An Encyclopedic Reference*. Academic Press, San Diego, CA, 2015; 597–611.
28. Bressler SL, Menon V. Large-scale brain networks in cognition: Emerging methods and principles. *Trends Cogn. Sci.* 2010; **14**: 277–290.
29. Squire LR, Zola-Morgan S. The medial temporal lobe memory system. *Science* 1991; **253**: 1380–1386.
30. Zhuo J, Fan L, Liu Y, Zhang Y, Yu C, Jiang T. Connectivity profiles reveal a transition subarea in the parahippocampal region that integrates the anterior temporal-posterior medial systems. *J. Neurosci.* 2016; **36**: 2782–2795.
31. Brevers D, Herremans SC, He Q *et al*. Facing temptation: The neural correlates of gambling availability during sports picture exposure. *Cogn. Affect Behav. Neurosci.* 2018; **18**: 718–729.
32. Lösel F, Bliesener T. Hooligan violence: A study on its prevalence, origins, and preventation. **In:** Dünkel F, Drenkhahn K (eds). *Youth Violence: New Patterns and Local Responses*. Forum Verlag Godesberg GmbH, Mönchengladbach, Germany, 2003; 245–265.