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Abstract

Studies have shown that attending to salient group relevant information could increase the BOLD activity across distributed neural networks. However, it is unclear how attending to group relevant information changes the functional connectivity across these networks. We investigated this issue combining resting states and task-based fMRI experiment. The task involved football fans learning associations between arbitrary geometric shapes and the badges of in-group, the rival and the neutral football teams. Upon learning, participants viewed different badge/shape pairs and their task was to judge whether the viewed pair was a match or a mismatch. For whole brain analyses increased activity was found in the IFG, DLPFC, AI, fusiform gyrus, precuneus and pSTS (all in the left hemisphere) for the rival over the in-group mismatch. Further, the ROI analyses revealed larger beta-values for the rival badge in the left pSTS, left AI and the left IFG. However, larger beta-values were found in the left pSTS and the left IFG (but not AI) for the in-group shape. The intrinsic functional connectivity analyses revealed that compare to the pre-task, post task functional connectivity was decreased between the left DLPFC and the left AI. In contrast, it was increased between the left IFG and the left AI and this was correlated with the difference in RT for the rival vs. in-group team. Our findings suggest that attending to group relevant information differentially affects the strength of functional coupling in attention networks and this can be explained by the saliency of the group relevant information.

Keywords	In-group, Intrinsic functional connectivity, Anterior insula, Inferior frontal gyrus, Dorsolateral prefrontal cortex

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Suggested reviewers	Pascal Molenberghs, Marco Tamietto, Diana Tamir

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Dear Editor

Thank you very much for giving us the chance to resubmit our revised paper. We sincerely appreciate your patience and generosity with our extension request. We would like to submit the attached revised paper to the Behavioural Brain Research to be considered for publication as a regular research paper. In light of the reviewers' comments in the revised paper we have added clear results regarding the whole brain analyses, the behavioural results as well as region of interest analyses. We believe that adding these extra analyses has strengthened our paper and will hopefully convince the reviewers as well as the editor that the group relevance affects the functional connectivity in the brain. We tried our best to respond to every comment made by the journal's nominated reviewers and we hope that the revised paper is satisfactory.

You're sincerely,

Zargol Moradi, Dante Mantini, Alla Yankouskaya, Miles Hewstone, (and on behalf of Glyn Humphreys)

Reviewer's comments

In this fMRI study, the authors test ed20 participants who have to learn to associate badges of their favourite team, a rival team and a neutral team with random geometrical shapes. The goal is to better understand of how in-group bias develops. Resting state scans are done before and after learning the associations. Behavioural results show that people associate the badges of their favourite team quicker and better than the other two conditions. The fMRI task shows that certain regions (DLPFC, AI, IFG, pSTS, etc) are more active during mismatch associations of the rival team (compared with own team). Resting state analyses reveal increased connectivity between left AI and IFG post task and the authors associate this with in-group bias. The question of how in-group biases develop is interesting but I have several major reservations in regards to how the study is operationalised and written up.

Response

First of all, we would like to thank the reviewer for taking time to read our paper and thanks for the constructive feedback. We agree that the previous version of our paper was not written in a clear structure and appreciate the chance to revise and resubmit our paper.

Comments:
Major:

1) The description of the details of the paper is pretty poor and is hard to follow. A couple of comments in relation to this:

a) - I would strongly suggest to rewrite the paper as a regular article rather than a short communication. The paper is now very hard to follow, with methods and other info all over the place and hidden in Supplementary Material. There is enough in this paper to write it up as a proper article.

Response

We like to thank the reviewer for suggesting to rewrite the paper as a regular article. The revised version has been rewritten as a regular article rather than a short communication. All the methods including three different analyses (whole brain, ROI and functional connectivity) are presented in the main body of the paper. We further added the behavioural results. So, together with the graphical summary of the results hopefully the revised version of the paper would be easier to follow.

b) - Track changes were still left in Supplementary Material which gives an unprofessional appearance.

Response

We are sorry about this. We made sure to submit the final version of the paper without a markup.

c) - Most importantly, it is not clear how the events in the fMRI design were modelled (time locked to which event?; hrf?; time derivative? Etc.).

Response

We like to thank the reviewer for this comment. In the revised version, we clarified this issue. We modeled the onset of each trial for each of the nine shape–badge pairings and used these as regressors convolved with the canonical hemodynamic response function.

2) The authors say the fMRI results are FWE corrected but details are not clear. FWE corrected for the whole brain? Voxel-threshold? Cluster-threshold? Normally an FWE voxel level threshold of 0.05 should be used corrected for the whole brain but then none of the regions in Table 1 would be significant (all have a Z-score of < 4.72).

Response

*We like to thank the reviewer for their attention to details. We clarified this issue in the fMRI method section at p. 9, we explain that : Reported statistically significant effects are based on the second level random effect analyses. Results of the whole brain analysis is reported using a height threshold of **p**-uncorrected <.001, and an extent threshold of **k** ≥ 70 voxels (560 mm3) at the whole brain level; these criteria have been shown to be corresponding to **p** <.05 corrected for multiple comparisons across the whole brain and was used by previous studies (Jacob et al., 2012; Poline, Worsley, Evans, Friston,1997; Sui et al., 2013).*

2) The fMRI design should be analysed as a 3x2 factorial design in SPM. Now the authors just say that there were certain regions more active during mismatch associations of the rival team (compared with own team). First, main and interaction effects should be explored and reported, and if any are significant they should be followed up.

Response

We like to thank the reviewer for this comments. With respect to our design and the specific questions that we had with regard to attention to

group relevant information/stimuli (could be both in-group and outgroup depending on the context) we decided to follow the same way of analyses that Sui et al.,(2013) used as our design is very similar to theirs. Therefore, we reported the results using separate t-contrasts for match and mismatch trials.

4) People should probably never do a correlation with neuroimaging data with just twenty participants (see for example Yarkoni, 2009). Given the multitude of ways to analyse the neuroimaging data and the in-group bias, the correlation is probably not a reliable result and should be removed or at least discussed in relation to this limitation.
Yarkoni, T. (2009). Big correlations in little studies: Inflated fMRI correlations reflect low statistical power—Commentary on Vul et al.(2009). Perspectives on Psychological Science, 4(3), 294-298.

Response

We like to thank the reviewer for this comments. We understand their concerns about the small sample size and the big correlation. In our discussion, we put emphasis on the fact that we should interpret the results of correlation analyses with caution and we also refer to Yarkoni (2009).

5) It is not clear to me what this paper tells us about learning in-group biases. People are faster at associating for an in-group. There is more activity for the rival mismatch condition. Why is this relevant? Why is associating a badge of a team with a random geometrical shape a relevant design for learning about in-group biases? To me this is not clear and the intro and discussion do not provide a good rational either.

Response

We like to thank the reviewer for this comments. In the revised version of the paper we explained our results in light of attention processes instead of learning framework. We believe that this is what our data is revealing. As we did not find any difference in the BOLD activity in the match trials for the in-group vs. rival (even though there was behavioural differences, ie, faster and more accurate responses). Intenestingly the results showed that, the BOLD activity was higher for the rival vs. in-group mismatch. This effect we think can be interpreted as some sort of social stroop effect where the brain responds more strongly to two sources of conflicting information (rival badge paired with in-group shape). This finding also makes sense with respect to the longer RT for the rival mismatch (responses to the rival mismatch pairs were significantly slower than those to the in-group). *This was reported in p 14 and shown in Figure 2(D). We hope that the results are clear now and the rational is strong.*

6) The description of the neuroscience literature on in-group biases is very limited in the intro and discussion. There are now several review articles on the topic (e.g., Cikara and Van Bavel, 2014; Molenberghs, 2013; Amodio, 2014) that might be worth exploring in more depth.
Cikara, M., & Van Bavel, J. J. (2014). The neuroscience of intergroup relations an integrative review. Perspectives on Psychological Science, 9(3), 245-274.
Molenberghs, P. (2013). The neuroscience of in-group bias. Neuroscience and Biobehavioral Reviews, 37, 1530-1536.
Amodio, D. M. (2014). The neuroscience of prejudice and stereotyping. Nature Reviews Neuroscience, 15(10), 670-682.

Response

We like to thank the reviewer for this comments and for suggesting these useful references. All three recommended references are added to our reference list as well as in text. We believe that adding these references made our paper richer and more coherent.

7) The discussion focuses almost solely on the AI-IFG connectivity effect (which in my view could also easily be a false positive given the variety of ways to analyse the resting state data) but other results are not really discussed. For example: Why more activation as shown in Table 1 for this contrast? Why are there no differences for the other contrasts? Why faster RT and accuracy for in-group associations?

Response

We like to thank the reviewer for this comments. We agree that our paper in its previous version was very limited in terms of discussion ng our findings. In the revised version we made every effort to try and explain each single finding in light of the current literature. We hope that in the revised paper our discussion is comprehensive and clear.

Minor:
1) Behavioural results: A figure with mean (and error bars) for RT and accuracy would be useful and please also provide exact values for each condition and indicate if it is in ms and %. Related to this, the authors write "A similar analysis of response accuracy also showed a significant main effect of matching condition, $F(1, 19) = 8.91$, $p < .008$" but the direction is never explained.

Response

We like to thank the reviewer for this comments. We are sorry for not presenting the results clearly in the previous version of the paper. In the

revised version, all findings are explained in terms of the direction. For example, with regard to this comment we added the following description in p. 14. Pairwise comparisons were conducted separately for the match and mismatch pairs. The results showed that, for the match pairs, the accuracy for the in-group pair was significantly higher than for both the neutral, $t(19) = 8.38$, $p < .001$ (mean difference ± SE = .14 ± .07) and the rival teams, $t(19) = 5.92$, $p < .001$ (mean difference ± SE = .12 ± .09).

We are confident that in the revised version results are clearly explained and hopefully the reviewer would be happy with the current version of the paper.

2) The authors write: "These findings indicate that social relevance can raise the salience of stimuli for perception and attention (6-8) and thus enhance the processing of information that is socially relevant - for example, stimuli associated with the self (4,9-10,15), a loved one (11) or one's in-group (12-14,16)." Although true, how the authors write it, it seems that this is only true for themselves, people they love or the in-group, but depending on the circumstances this could also be for others, people they hate and outgroup people. For example when under attack, outgroup members might be more relevant than in-group members (see e.g., Molenberghs et al., 2014).
Molenberghs, P., Gapp, J. Wang, B., Louis, W. R. Decety, J. (2014). Increased moral sensitivity for outgroup perpetrators harming in-group members. Cerebral Cortex.

Response

We agree with this point and highlighted this in introduction as well as discussion. Further, we used the recommended references by the reviewers to put emphasis on specific condition where rival becomes more salient than the in-group.

3) The authors write in relation to the default mode: "(19; see also supplementary references 26, 27)."

Reference 27 is about "default mode in monkeys". There are probably more relevant references that could be given.

Response

We would like to thank the reviewer for this comment. We agree that the aforementioned reference might not be directly relevant to our study and therefore we removed it the from our reference list.

4) A figure with the task would be very useful.

Response

We like to thank the reviewer for this comments. In the revised paper, Figure 1 depicts the task used in our fMRI experiment.

5) The description of Table 1 says "Activation statistics and MNI coordinates linked to the social associative learning task." but it is not clear from this description what contrast the table is referring to.

Response

We like to thank the reviewer for their attention to details. We are sorry for leaving this information unexplained. In the revised version in the Table legend we explained that these areas are activated for the rival > in-group mismatch pairs. This can be found in p. 18 in Table 1.

6) The authors write: "These regions have been shown to be involved in social salience processing across fMRI tasks (see supplementary references 29-32)." This is a very limited description/discussion of the results in Table 1 and very uninformative. For example, the Cunningham study was about face processing and this study not at all, so why would we expect the fusiform area for example in Table 1.

Response

We like to thank the reviewer for this comments. This was explained in more details in the revised version of the task in Discussion section.

7) The authors write: "Figure 1. Example activation map related to task performance vs. rest (N=20)." Again an example of the relevant nonchalant reporting in this paper. What is an "example activation map"? What does performance vs. rest mean? Threshold should not start at 0 but at significant threshold. Etc.

Response

We like to thank the reviewer for attending to details. We agree that Figure 1 in the previous version of the task was vague and not speaking for our results. This was removed from the revised version.

8) The authors write: "In total, we compared the functional connectivity of 15 pairs (seeds). Where do the 15 comparisons come from? Why 15? Why these?

Response

We like to thank the reviewer for this comments. Since we had 6 ROI as seeds in the functional connectivity analyses we ended up with 15 pair of

regions to compare for the correlational analyses regarding functional connectivity. We hope that this is clear now. Also, all 15 pairs are presented in Table 2 p. 19.

9) “t(19) = 2.80, p < .003” => Table 2 says it is 0.03 so it should be “=”

Response

We like to thank the reviewer for their attention to details. This has been changed in the revised version of the paper.

Changes in intrinsic functional connectivity and group relevant salience: The case of sport rivalry

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Abstract

Studies have shown that attending to salient group relevant information could increase the BOLD activity across distributed neural networks. However, it is unclear how attending to group relevant information changes the functional connectivity across these networks. We investigated this issue combining resting states and task-based fMRI experiment. The task involved football fans learning associations between arbitrary geometric shapes and the badges of in-group, the rival and the neutral football teams. Upon learning, participants viewed different badge/shape pairs and their task was to judge whether the viewed pair was a match or a mismatch. For whole brain analyses increased activity was found in the IFG, DLPFC, AI, fusiform gyrus, precuneus and pSTS (all in the left hemisphere) for the rival over the in-group mismatch. Further, the ROI analyses revealed larger beta-values for the rival badge in the left pSTS, left AI and the left IFG. However, larger beta-values were found in the left pSTS and the left IFG (but not AI) for the in-group shape. The intrinsic functional connectivity analyses revealed that compare to the pre-task, post task functional connectivity was decreased between the left DLPFC and the left AI. In contrast, it was increased between the left IFG and the left AI and this was correlated with the difference in RT for the rival vs. in-group team. Our findings suggest that attending to group relevant information differentially affects the strength of functional coupling in attention networks and this can be explained by the saliency of the group relevant information.

Keywords: In-group, Intrinsic functional connectivity, Anterior insula, Inferior frontal gyrus, Dorsolateral prefrontal cortex

Introduction

Belonging to a group is an essential need for human beings (Turner, 1987). Accumulating evidence suggests that in-group identification leads to categorizing the 'self' and the 'others' into in- and out-groups (Tajfel, 1982) and this subsequently affects different aspects of human cognition including attention, memory, learning and decision making (Insel & Fernald, 2004; Moradi, Yankouskaya, Duta, Hewstone, & Humphreys, 2016; Moradi, Sui, Hewstone, & Humphreys, 2015; Sui, He, & Humphreys, 2012; Wentura, Rothermund, & Bak, 2000; Wyer Jr, & Srull, 2014; Yankouskaya, Humphreys, & Rotshtein, 2014).

Much effort has been made into understanding how the brain responds to the group relevant information across different contexts. Using brain imaging techniques, mainly task-based fMRI, previous studies shed some light on the neural underpinnings of these effects revealing the contribution of different regions of the brain involved in attention to the group relevant information. In line with this, previous neuroimaging studies have shown enhanced BOLD response across distributed regions (depending on the task) in the brain for the in-group over outgroup stimuli (Gutsell, J. N., & Inzlicht, 2010; Morrison, Decety, & Molenberghs, 2012; Van Bavel, Packer, & Cunningham, 2008).

However, some studies showed the opposite and revealed stronger BOLD response to outgroup over in-group stimuli (Cikara, & Van Bavel, 2014; Cikara, Botvinick, & Fiske, 2011 Molenberghs, Gapp, Wang, Louis, & Decety, 2014).
The findings notably indicate that depending on the context different regions within dorsal and ventral attention networks play role in attention to group relevant information. These networks include areas in anterior cingulate, medial prefrontal, posterior superior

temporal sulcus, fusiform face area, anterior insula, dorsal prefrontal cortex and the amygdala (for review see Amodio, 2014; Molenberghs, 2013).

Together, these findings suggest that depending on the context, the information/stimulus assigned to in- or out-group could gain the salience and this could differentially affect BOLD activity in different areas in the brain. However, it is still unclear how such group relevant saliency relates to the changes in functional connectivity across these networks. Current accounts do no explain the nature of communication between different areas in the brain shown to contribute to group relevant saliency. One way to better understand this is to combine the resting state and task-based fMRI techniques. Previous studies have established that the low-frequency neural activity in different regions of the brain when no task is being performed (resting state neural activities) reflects the strength of functional connectivity between the brain regions which operate in coordination as a part of an underlying neural network (Damoiseaux et al., 2006; Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008; Mantini, Perrucci, Del Gratta, Romani, & Corbetta, 2007). Resting state functional connectivity studies could provide a measure of the integrity as well as changes in the neural networks important for attention to group relevant information.

To investigate this issue, in our study we used a novel social association task with football fans. Participants learnt to associate simple geometric shapes with the badges of their favourite football team (the in-group), its closest rival, and a neutral team (the latter two being outgroups). Subsequently, participants viewed different badge/shape pairs and their task was to indicate whether the viewed pair was a match or a mismatch using two separate keys inside the scanner.

Brain imaging was conducted prior to participants performing the social association task (pre-task resting state), during the task (on task fMRI), and then again

when at rest after completing the task (post-task resting state). We applied a two-stage analysis approach. Firstly, we selected regions of interest (ROIs) using the areas activated during the social association task. Secondly, we used these ROIs as seeds in order to explore the changes in resting state functional connectivity from before to after the social association task was performed. By comparing resting state activity before and after the task for each participant, we evaluated changes in underlying functional activity while controlling for individual differences at the baseline (Mantini et al., 2007). Further, we evaluated the correlation between changes in pre- and post-task functional connectivity with the differences in behavioural performance (response time and accuracy) in the social association task.

In the social association task, we used the badges of three different football teams two of them being traditional rivals (even though not being in the same league at the time of our experiment). Using sport conflict, we maximised the chances of finding differences in brain activation when it came to attending to the salient group relevant stimuli. Moreover, focusing on changes in intrinsic functional connectivity helped us to better understand the neural dynamics underlying group relevant attention processes. This has not been investigated in the previous studies.

We might expect to see modulation of responses to in-group stimuli similar to those found with self-associated items in the ventral attention network (see, Sui et al., 2013). An alternative, though not mutually exclusive proposal, is that group differences in attention processes might be related to the less positive association with the outgroup (Avenanti, Sirigu, & Aglioti, 2010; Mathur, Harada, Lipke, & Chiao, 2010) resulting in greater activity in the areas such as the anterior insula, the anterior cingulate cortex (see Amodio, 2014) and the precuneus (Bruneau & Saxe, 2010; Cavanna & Trimble, 2006), known to modulate attention to outgroups relevant stimuli. This is particularly important

in competitive contexts such as sport rivalry where outgroup derogation has prominent motivational influences on group relevant information processing.

Method

Participants

Twenty healthy (one female) right-handed volunteers, aged between 21-45, mean (SD) = 31 (7.50), with normal or corrected-to-normal vision and with no history of any neurological condition, took part in the study. Prior to the experiment, all participants signed a written informed consent form approved by the University of Oxford Medical Science Ethics committee.

Stimuli and task

Three geometric shapes (pentagon, square, and triangle) were presented, with each shape paired with a badge of one of the three different football teams. The teams were the participants' favorite football team (the in-group), its traditional rival team, and a neutral team (which participants neither liked nor disliked but were familiar with).

Participants were instructed to learn the association between each pair of shape and badge. The assignment of each shape to a particular badge (in-group, rival, neutral) was counterbalanced across participants. The shape and the badge (160×160 pixels, corresponding to 4.5 × 6.5 degree of visual angle) were presented at approximately 3˚ above or below the fixation cross (1˚× 1˚) at the center of the screen on a fifty percent grey background and the order of the trials was randomized. Stimuli were presented on a screen situated 1.5 meters away from the subject, inside the magnetically shielded room and displayed via projector (refresh rate 60Hz) situated outside the room. Stimulus presentation and timing was controlled using Presentation software (Neurobehavioural Systems, Albany, CA).

Each trial began with a fixation cross for 500 ms. followed by the simultaneous presentation of a badge and shape for 500 ms. and there was a response time limit of 1500 ms. During a period of 2000 to 6000 ms. (jittered), a fixation point was presented on the center of the screen. Participants were trained on the task using a set of 3 pairs (badge and shape), briefly prior to scanning in an initial practice block of 12 trials. The associations for each stimulus were maintained throughout the scanning session. Scanning runs consisted of 81 trials per run and all participants completed 6 runs for the total of 486 trials.

Before the experiment, participants were asked to complete a 'badge familiarity' survey. In this survey participants rated the level of familiarity of the badges of 12 different football clubs including their favourite team and the traditional rival team from 1 (*not familiar*) to 7 (*perfectly familiar*). Furthermore, participants were asked to report how much they like/dislike each team. The liking/disliking ratings were based on a 7-point scale from -3 (strongly disliked) to 3 (strongly liked). To assess the nature of each fan's identification with their team, we adapted a multicomponent social identity questionnaire, which measures relatively stable levels of 'belongingness' to relevant social categories (Leach et al., 2008). To evaluate each participant's commitment to their favourite team, participants were also asked to report the number of matches they attend (including home and away matches) per season, at what age they started to support their team and finally whether they donated money to support their football club financially. A schematic representation of the task used in the fMRI Experiment is shown in **Figure 1.**

Figure 1. about here

Image Acquisition

The images were acquired on a 3-T SIEMENS MRI scanner (Erlangen, Germany) using a 24-channel SENSE head coil. T1-weighted anatomical images were acquired with TR = 2040 (ms), TA: 5:56 (minutes), TE = 4.7 (ms), flip angle = 8°, FOV = 192 (mm), and slice thickness of 1.0 (mm). Functional images were acquired with a gradient echo T2*-weighted echo-planar sequence with TR = 2300 (ms), TA: 7:08 (minutes), TE = 30 (ms), flip angle = 90°, FOV = 192 (mm), and slice thickness 3.0 (mm). A total of 42 axial slices (3 mm thick) were sampled for the whole-brain coverage. In total, there were six runs of the fMRI task. There was one run of resting state before the task and one run after the task. In each run, 183 volumes were acquired. During the two resting state data acquisition (before and after the task) sequences with each lasting around 7:08 minutes, participants were asked to stay still and keep looking at the white fixation cross in the middle of the black screen.

Image Analyses

The collected imaging data (task-related fMRI and resting state) were preprocessed using SPM8 (Wellcome Trust Centre for Neuroimaging).

Preprocessing

Preprocessing of functional images included realignment, unwarping, slice-timing correction, and co-registration to the participant's T1 scan. Low- frequency signal drift was corrected for by applying a high-pass temporal filter with a cut-off of 128 s. The co-registered images were subsequently normalized onto the Montreal Neurological Institute (MNI) template with a spatial resolution after normalization of 3 × 3 × 3 mm. The resulting normalization parameters were applied to all the resting state images. The functional data were spatially smoothed using an 8-mm isotropic Gaussian Kernel. The movement parameter was visually inspected to make sure that it fell under

the maximum limit of 1.5 mm for all participants. For the resting state fMRI data, only, we applied additional preprocessing steps to remove spurious sources of variance in preparation for the functional connectivity analysis (Gillebert, & Mantini, 2013). This was performed by using self-devised MATLAB scripts (The Mathworks Inc, Natick, MA) and included (1) scrubbing of motion-affected functional volumes; (2) bandpass filtering between .009 and .08 Hz; (3) regression of white matter, ventricle signals, and their first derivatives; (4) regression of 3-dimensional motion parameters and their first derivatives. No global signal regression was applied (Gillebert, & Mantini, 2013).

Whole brain analyses

For the whole brain analyses, we followed a similar procedure used by Sui and colleagues (2013). We first computed the mean estimated BOLD response across the six runs for each participant. For the second level, a random effect analysis was tested by using a factorial design including nine badge-shape pairs in total 3 match and 6 mismatch pairs (three shapes × three labels). We modeled the onset of each trial for each of the nine shape–badge pairings and used these as regressors convolved with the canonical hemodynamic response function. To control for the effect of error, only correct responses were included.

Reported statistically significant effects are based on the second level random effect analyses. Results of the whole brain analysis is reported using a height threshold of $p_{\text{uncorrected}} < .001$, and an extent threshold of $k \geq 70$ voxels (560 mm3); these criteria have been shown to be corresponding to $p < .05$ corrected for multiple comparisons across the whole brain and was used by previous studies (Jacob et al., 2012; Poline, Worsley, Evans, Friston,1997; Sui et al., 2013). In our study, the whole brain analysis was conducted separately for match and mismatch trials.

Match trials: We used t-contrast analyses to assess brain regions associated with increasing or decreasing activity for in-group as oppose to the rival and neutral associations. These contrasts included in-group > rival, in-group > neutral, neural > rival; in-group < rival, in-group < neutral, and neutral <rival.

Mismatch trials: Following similar procedure used by Sui et al., (2013) we then conducted t-contrast analyses for the mismatch trials comparing the in-group with neutral and rival mismatch trials for increasing or decreasing BOLD response in the brain. The contrasts for the mismatch trials were organized based on the badge of each team (in-group, neutral and rival teams). In total, there were six mismatch pairs (two per each football team) including ***in-group badge***/rival shape, ***in-group badge***/neutral shape; ***rival badge***/in-group shape, ***rival badge***/neutral shape; ***neutral badge***/in-group shape; ***neutral badge***/rival shape. We were specifically interested to compare and contrast the effect of in-group and rival badge when paired with the shape associated with the ***opposing team***. The in-group badge condition measured the effect of the in-group badge (paired with either a rival- or neutral-associated shape); the in-group shape condition measured the effect of a in-group-associated shape (paired with either a neutral or rival badge); the neutral-rival pairs were used as a baseline and included the pairs when rival and neutral shape/badge (or vice versa) were presented as a pair.

Region of interest analyses

Region of interest (ROI) analyses were conducted to examine the more specific contribution of the different activated clusters in the univariate analyses to the task. The ROI analyses focused on three brain regions that have been found to be linked to social attention – the left posterior superior temporal sulcus (pSTS) (Sui, Rotshtein, & Humphreys, 2013), the left anterior insula (AI) (Kurth Zilles, Fox, Laird, & Eickhoff, 2010) and the left inferior frontal gyrus (IFG) (Molenberghs, Cunnington, & Mattingley,

2012). Each ROI (left pSTS, left AI and left IFG) was defined as a sphere (6 mm.) centered on a peak voxel in the empirical study of Sui and colleagues (2013), the meta-analysis of Kurth et al. (2010) and the meta-analysis of Molenberghs, Cunnington, & Mattingley (2012). MNI coordinates were converted to Talairach coordinates using a non-linear transformation (http://imaging.mrccbu. cam.ac.uk/imaging/MniTalairach). Brodmann areas and brain regions were identified based on the Talairach Atlas (Talairach & Tournoux, 1988). The co-ordinates for the left pSTS region were centered on *x= -52, y=-62, z= 16* (Sui et al., 2013). The co-ordinates for the left AI region were centred on *x= -35, y=18, z= 7* (Kurth et al., 2010). The co-ordinates for the left IFG region were centred on *x= -50, y=20, z= 14* (Molenberghs, Cunnington, & Mattingley, 2012). We conducted three separate ANOVAs to examine whether there was any effect of the group relevance on the magnitude of signal change (beta values) for each ROI.

Functional connectivity analyses

The peak voxel within the activated cluster in the task were used as seeds for the resting state functional connectivity analyses. Based on this, we created the ROIs using the Marsbar toolbox (http://marsbar.sourceforge.net). The seeds were composed of 6-mm radius spheres centred on the selected predefined peak voxels. The size of the spheres was based on previous studies using the same method (Gillebert, & Mantini, 2013). We then compared and contrasted the strength of functional connectivity between each pairs of seed under resting state for post- vs. pre- task conditions.

The functional connectivity analysis was performed using self-devised MATLAB scripts (Gillebert, & Mantini, 2013). First, the resting state fMRI series across all voxels in each seed were averaged. Next, the correlation strength between every pair of seeds was calculated using Pearson correlation coefficients. These processes were repeated for the pre-task as well as the post-task resting state. Next, the correlation of

pre- vs. post-task BOLD activity for each pair of seed was computed. The Pearson correlation values were converted to z-scores by Fischer's r-to-z transformation {z = 0.5 Ln [(1 + r)/(1 − r)]}. A random-effects analysis was used to create group-level correlation matrices. Here, correction for multiple comparisons was applied using the Bonferroni procedure (Genovese, & Wasserman, 2002). We used paired t-tests to directly compare the strength of functional connectivity between seeds before and after the task. We then investigated whether or not performance in the task (reaction time and accuracy) correlated with the changes in the strength of functional connectivity of certain areas within the seeds of interest. To do so, z-values for functional connectivity that showed a significant difference before and after the task were extracted and the correlation with the difference in behavioural performance for in-group vs. rival stimuli were computed.

Results

Behavioural data

Ratings

The familiarity ratings were based on a 7-point scale from 1 (*not familiar*) to 7 (*perfectly familiar*). The mean (SD) familiarity ratings were: in-group = 6.90 (±.30), rival = 6.35 (±.58), neutral =5.56 (±.48). These ratings differed across the teams, $F(2,38)= 39.07$, $p < 001$, $\eta^2 = .673$. This was due to the in-group team being rated as more familiar than the rival, $t(19)=3.58$, $p = .002$, $d = .80$, and the neutral team, $t(19) =10.16$. $p < .001$, $d = 2.27$. Moreover the rival and the neutral team differed significantly in terms of their rated familiarity, with the rival team being rated as more familiar than the neutral team, $t(19) = 4.76$, $p < .001$, $d = 1.06$.

The mean (SD) liking/disliking ratings were also based on a 7-point scale from -3 (*strongly dislike*) to 3 (*strongly like*): in-group = 3.00 (±00), rival -2.35 (±.87), neutral

=.25 (±.44). On average the in-group team was more liked and the rival team was more disliked than the neutral team, which was rated close to the mid-point of the scale (0). These ratings differed across the teams, $F(2,38) = 439.86$, $p < .001$, $\eta^2 = .959$, with the in-group team being rated as more liked than both the rival, $t(19) = 27.34$, $p < .001$, $d = 6.11$, and the neutral team, $t(19) = 27.68$, $p < .001$, $d = 6.19$.

On average (mean ± SD) participants attended 28.45(±10.37) matches per year and donated £ 68.50(±58.33) to support their team. On average participants started to support their favourite team at the age of 6(±2.5). The mean (SD) score for the subcomponents of the multicomponent in-group identification questionnaire were solidarity = 18.25 (±2.33, max 21), satisfaction = 24.85 (±2.41, max 28), centrality = 17.30 (±2.90, max 21), in-group homogeneity = 10.45 (±2.35, max 14) and self-stereotyping =10.40 (±2.54, max 14). Across individuals we found positive correlations between the measure of satisfaction with the in-group and the number of matches attended, $r = .81$, $p < .001$, $N = 20$. There was also a reliable positive correlation between the number of matches attended and the money donated, $r = .52$, $p = .02$, $N = 20$.

Reaction time and accuracy

We used a repeated measures analysis of variance (ANOVA) on reaction times (RTs) with matching condition (match vs. mismatch) and group relevance (in-group vs. rival and neutral) as within subject factors. This revealed a significant effect of matching condition on RT, $F(1, 19) = 26.60$, $p < .001$, $\eta^2 = .58$, with RTs being faster for the match compared to the mismatch pairs (mean difference ± SE = 53.37 ± 10.32). Moreover, the effect of group relevance was significant, $F(2, 38) = 36.88$, $p < .001$, $\eta^2 = .66$. The interaction between matching condition and group relevance was also significant, $F(2, 38) = 12.74$, $p < .001$, $\eta^2 = .40$. To decompose the interaction, we

conducted post hoc analyses separately for the match and mismatch pairs. Pairwise comparisons on match pairs showed that the responses to in-group pairs were significantly faster compared to the rival, $t(19)= 9.03$, $p <.001$, $d = 2.20$, and the neutral teams, $t(19)= 6.05$, $p < .001$, $d = 1.35$, which did not significantly differ from one another, $t(19)= 1.24$, $p = .22$. Pairwise comparisons on mismatch pairs also revealed that responses to the in-group mismatch pairs were significantly faster than those to the rival, $t(19)= 4.12$, $p < .001$, d= .92, and neutral teams, $t(19)= 3.22$, $p = .004$, $d =.74$. However, the RTs for the rival and the neutral teams did not differ, $t(19)= .72$, $p = .47$.

A similar analysis of response accuracy also showed a significant main effect of matching condition, $F(1, 19) = 8.91$, $p = .008$, $\eta^2 = .32$, as well as group relevance, $F(2, 38) = 24.04$, $p < .001$, $\eta^2 =.56$. Furthermore, the interaction between matching condition and group relevance was also significant, $F(2, 38) = 20.85$, $p < .001$, $\eta^2 =.52$. Pairwise comparisons were conducted separately for the match and mismatch pairs. The results showed that, for the match pairs, the accuracy for the in-group pair was significantly higher than for both the neutral, $t(19) = 8.38$, $p < .001$, $d =1.87$, and the rival teams, $t(19) = 5.92$, $p < .001$, $d = 1.32$, which did not significantly differ , $t(19) = 1.24$, $p = .23$. However, the effect of group relevance was not significant for the mismatch pairs, $p = .70$. **Figure 2 (A to E)**. depicts the graphical summary of the behavioural results.

Figure 2. About here

Neuroimaging data

The results regarding neuroimaging data are presented in three sections. We first, present the findings related to the whole brain analyses, following by the ROI and functional connectivity analyses.

Whole brain analyses

Match trials: On the match trials the contrasts between in-group and rival or neutral pairs did not result in any significant activation (in-group vs. rival and in-group vs. neutral) no significant difference in decreasing or increasing BOLD response was observed. Also, the contrast for the neutral vs. rival (rival > neutral and rival < neutral) did not result in any significant activation.

Mismatch trials: When the data were organized by the badge of each team, there was decreased activity for in-group vs. the rival mismatch pairs (in-group < rival) in multiple clusters including the left lateral frontal and prefrontal cortices, left anterior insula, left intra-parietal sulcus, left precuneus and left fusiform area. Decreased activity was also found for the in-group vs. the neutral mismatch pairs (in-group < neutral) in a distributed network largely overlapping with some of the regions found for the in-group < rival contrast.

The regions containing peak activation differences regarding these two conditions included the left and right anterior insula, the left inferior frontal gyrus and the left fusiform gyrus. The reverse contrasts (in-group > neural and in-group > rival) did not result in any significant activity. More details regarding the activation statistics in the task can be found in Table 1.

ROI analyses

Since the whole brain analyses revealed the statistically significant activity only for **mismatch trials** in the ROI analyses we focused on mismatch trials only. The mismatch trials were analyzed in two different ways. First based on the badge that was presented and then based on the shape associated with each team.

Mismatch trials organised by badge: For mismatch trials organised by badge the mean (SD) beta values in left pSTS were: neutral =.28±1.03, in-group =.19±.74 and

rival=.58±.97. We used a repeated measure ANOVA to investigate the effect of group relevance of the badge (three levels in-group, neural and rival) on the magnitude of BOLD activity (beta values) in the left pSTS. The ANOVA results showed that there was a significant main effect of the group relevance on the magnitude of beta values in the left IFG, $F(2,38)= 5.19$, $p= .010$, $\eta^2=.215$. Pairwise comparisons revealed that the beta values in the left pSTS were significantly larger for the rival mismatch pairs (organised by badge) than the in-group, $t(19)=3.46$, $p= .003$, $d =.77$. The beta values in the left pSTS were also larger for the rival compared to the neutral mismatch trials, but the difference was not significant (corrected for multiple comparisons), $t(19)= 2.05$, $p=.054$, $d=.45$. The difference between the in-group and neutral conditions was not significant, $t(19) =.80$, $p=.429$.

The mean (and SD) beta values in the left AI were neutral = .72±.69, in-group = .56±.73 and rival=.82±.84. The ANOVA results revealed that there was a significant effect of group on the size of beta values in the left AI, $F(2,38)=3.78$, $p= .032$, $\eta^2=.166$. Pairwise comparisons revealed that on average the beta values were larger for the rival compared to the in-group, $t(19)=2.46$, $p= .023$, $d=.55$. However, the effect was not significant (after correction for multiple comparison). The differences between the beta values for the in-group versus neutral, $t(19)=1.48$, $p= .155$, and neutral versus rival, $t(19)=1.47$, $p=.157$, were not significant.

The mean (and SD) beta values in left IFG were neutral = .50±.79, in-group = .23±.69 and rival=.66±1.01. The ANOVA results showed that there was a significant main effect of group on the magnitude of beta values in the LIFG, $F(2,38)= 6.18$, $p = .005$, $\eta^2=.245$. Pairwise comparisons revealed that, for the mismatch trials, the beta values in the left IFG were significantly larger for the rival than for the in-group, $t(19) = 3.56$, $p=.002$, $d=.79$. The beta values in the left IFG were also larger for the neutral than

the in-group condition, but this was not statistically significant (corrected for multiple comparison), $t(19)= 2.19$, $p= .044$, $d=.48$. The beta values in the left IFG for the neutral mismatch team were not significantly different from those of the rival team, $t(19)= 1.27$, $p=.219$.

Mismatch trials organised by shape: For the mismatch trials organised by the shape associated with each team, the mean (and SD) beta values in the left pSTS were: neutral = .38±1.05, in-group=.50±.95 and rival = .18±.71. There was a significant main effect of the group, $F(2,38)= 3.63$, $p = .036$, $\eta^2=.160$. Pairwise comparisons revealed that the beta values were significantly larger for the in-group shape (on mismatch trials) than the rival shape, $t(19)= 3.05$, $p= .007$, $d= .68$. The difference between the in-group versus neutral shape, $t(19)= .87$, $p< .39$, and neutral versus the rival shape $t(19)= 1.71$, $p = .102$, were not significant.

The mean (and SD) beta values in the left AI were: neutral = .78±.98, in-group = .68±.65 and rival = .64±.63. The results of the ANOVA showed that the main effect of the group on the magnitude of beta values in the left AI was not significant, $F(2,38)=.78$, $p = .462$, $\eta^2=.040$.

The mean (and SD) beta values in the left IFG were neutral= .51±.99, in-group=.60±.78 and rival = .29±.71. The results of the ANOVA showed that there was a significant main effect of group relevance on the beta values in the left IFG, $F(2,38)=3.61$, $p= .047$, $\eta^2=.160$. The beta values were significantly larger for trials organized by the in-group rather than the rival shape, $t(19)=3.55$, $p =.002$, $d = .79$. However, the difference between the in-group trials and the neutral trials, $t(19) = .75$, $p = .457$, and between the neutral and rival trials were not significant, $t(19)=1.56$, $p = .134$.

Figure 3 (A to C) depicts the graphical summary of ROI results.

Figure 3. About here

Functional connectivity analyses

Based on the whole brain and ROI analyses we used six different regions as seeds for the functional connectivity analyses. For the functional connectivity analyses, we focused on the regions showing increased BOLD activity for the rival versus in-group mismatch contrast. These regions are shown in **Table 1.**

Table 1. Brain regions linked to the rival/in-group mismatch association at $P < 0.001$ uncorrected at the whole brain level and an extent threshold of >70 voxels. *Note*: these regions were used as seeds in intrinsic functional connectivity analyses.

	Cluster size	***Peak voxel(MNI)***			
Region	**K**	**X**	**Y**	**Z**	**Z-score**
Left DLPFC	270	-36	14	31	4.16
Left AI	195	-42	32	4	4.11
Left IFG	77	-51	20	10	3.06
Left Fusiform area	183	-33	-61	-14	4.11
Left pSTS	221	-42	-40	64	3.68
Left precuneus/posterior cingulate	127	-21	-76	46	4.26

Having 6 seeds of interest, in total, we ended up comparing the functional connectivity of 15 pairs (seeds). Therefore, the significance level for the functional connectivity was adjusted for multiple comparisons and only pairs with $p \leq .003$ (.05/15) were considered as significant. See **Table 2.** for more details on the changes in functional connectivity for all 15 pairs.

Table 2. Changes in the strength of functional connectivity for each pair in post- vs. pre-task.

Pair ROI	*t-value (post vs. pre task)*	*p-value*
AIC/DLPFC	-1.54	.065
AIC/IFG	2.80	.003*
AIC/Precuneus	-1.67	.051
AIC/Fusiform	-.86	.195
AIC/pSTS	1.90	.031
DLPFC/IFG	-3.38	.001**
DLPFC/Precuneus	-.89	.189
DLPFC/Fusiform	-1.73	.045
DLPFC/pSTS	.11	.453
IFG/Precuneus	-2.02	.025
IFG/Fusiform	.44	.330
IFG/pSTS	1.28	.102
Precuneus/Fusiform	1.36	.089
Precuneus/pSTS	1.51	.068
Fusiform/PSTS	-.71	.239

Our results showed that, compared to pre-task, the strength of post-task functional connectivity between the left anterior insula (AI) and the left inferior frontal gyrus (IFG) was significantly increased, $t(19) = 2.80$, $p = .003$, d=.62. Furthermore, there was a reliable decrease in the strength of functional connectivity between the left dorsolateral prefrontal cortex (DLPFC) and the left AI, $t(19) = -3.34$, p =.001, d= .74, in the post- compared to the pre-task condition.

Next we tested the correlation between the functional connectivity and the performance in the social associative learning task. As we only used the correct responses for our fMRI analyses the correlational analyses was based on the difference between the RTs for different conditions. We used the difference between the RT for the

participant's own team and the rival team as a measure of "*in-group bias*". This was computed separately for match and mismatch trials. However, since the BOLD response was significant only for the mismatch trials, in our correlation analyses we focused on the **mismatch** conditions contrasting **in-group** versus **rival** teams and did not include the match trials. Our results showed that the changes in the post- vs. pre-task functional connectivity between the left AI and left IFG significantly positively correlated with the size of the RT-based in-group bias for the mismatch trials ($r = .63$, $p = .002$, $N = 20$).

In contrast, the correlation between the RT-based in-group bias for the mismatch trials and the changes in functional connectivity for DLPF/AI was not reliable ($r = .061$, $p = .808$, $N = 20$). There was also no significant correlation between the increase in the functional connectivity between (i) the IFG and the AI and (ii) the decrease in connectivity between the AI and the DLPFC ($r = .102$, $p = .661$, N=20). We further tested whether pre-task functional connectivity between the AI and i) DLPFC, and ii) IFG was correlated with in-group bias. Our results showed that in-group bias was not significantly correlated with pre-task functional connectivity for the left AI and either i) DLPFC, $r = .228$, $p = .334$, N=20, or ii) IFG $r = .407$, $p = .075$, $N = 20$. **Figure 4 (A to E)**. depicts the graphical summary of functional connectivity analyses results.

Figure 4. About here

Discussion

In the current study, we investigated how the changes in intrinsic functional connectivity across distributed areas in the brain including some parts of ventral and dorsal attention networks relates to group relevant salience processes. We assessed whether, in a group of passionate football fans, performance on the social association

task altered intrinsic functional connectivity in the brain, contrasting post- vs. pre-task resting state fMRI. These investigations were complemented by the whole brain and the region of interest analyses of fMRI data. We further evaluated whether there was any relationship between the behavioural performance in the task and the changes in intrinsic functional connectivity.

In the whole brain analyses, we did not find reliable differences between different match trials. However, there were effects of group relevance on mismatch trials. When mismatch trials were organized by the badges of the different teams we found increased activity in the IFG, DLPFC, AI, fusiform gyrus, precuneus and pSTS (all in the left hemisphere) for the rival over the in-group team badge. Further, the ROI analyses revealed larger beta values for the rival badge in the left pSTS, left AI and the left IFG. However, larger beta values were found in the left pSTS and the left IFG (but not AI) for the in-group shape. The intrinsic functional connectivity analyses revealed that compare to the pre-task, post task functional connectivity was decreased between the left DLPFC and the left AI. In contrast, the functional connectivity was increased between the left IFG and the left AI. Furthermore, the strength of post-task functional connectivity was correlated with the difference in RT for the rival vs. in-group team.

In line with our findings, previous studies have shown that the activity in the DLPFC and IFG mediate general cognitive and attention control (Corbetta & Shulman, 2002). Involvement of these areas while viewing the mismatch pairs is consistent with participants requiring increased attention to respond to that specific mismatch pairs. The IFG and DLPFC form a part of a dorsal attentional control network that might be recruited when the rival badge was present perhaps because this badge was perceived as more salient by the opponent team fans.

Our findings regarding the ROI analyses and the increased activity in the left pSTS for the in-group shape is in line with the findings that Sui et al. (2013) reported involving the enhanced activity in the left pSTS to the stimulus associated with self in comparison with those associated with other people. They suggested that this finding reflects an increased attention to the self-relevant stimulus. Here, increased activity in the left pSTS was found when the shape associated with the in-group appeared with a mismatch badge. Our results extend Sui et al.'s (2013) findings indicating that the left pSTS modulates attention to both self and in-group relevant stimuli.

Furthermore, the ROI analyses confirmed that the magnitude of BOLD response (based on the extracted beta values) both in the left pSTS and the left IFG was significantly larger for the in-group shape than the rival shape or vice versa for the rival badge than the in-group badge. These results are very interesting since they might show the higher salience of the pair consisted of rival badge and in-group shape for the brain. This specific pairing that contains both in-group and rival relevant stimuli might somehow produce the stroop-like response in the brain. Indeed, previous studies have shown that the left IFG is involved in response inhibition in the tasks such as Stroop colour-word requiring cognitive control (see for example, Milham et al., 2001). Here, we propose that the social association task that we used might also require the inhibition of "*yes*" response for the mismatch trials containing both the in-group and rival relevant stimuli and this in turn increased the level of activity in the left IFG and the left pSTS. The Stroop effect concerns the conflict between two different classes of information (usually color and word). This task and other conflict-related tasks measure the ability to suppress the more dominant response (Petersen & Posner, 2012). Neuroimaging studies (see Fan et al. 2003a) have shown that the brain responds similarly to the conflict regardless of its modality. For example, spatial, word-color, and pictorial conflicts all

seem to share similar neural networks. The networks involved in cognitive conflict includes anterior insula (Dosenbach et al. 2007; Sridharan et al. 2007, 2008), anterior cingulate (Bush et al. 2000) and prefrontal cortex (Fan et al. 2003a). Here, we proposed that the heightened BOLD activity in response to the pairing of the rival badge and in-group shape reflects brain's response to a specific class of stroop effect, perhaps some sort of social stroop effect.

In line with this interpretation, we further found increased activity in the anterior insula and precuneus when viewing rival badge paired with in-group shape. It is worth noting that these areas have been associated with a number of different cognitive functions generally involving attention to social stimuli (Amodio, 2014; Bruneau & Saxe, 2010). The anterior insula in particular has been linked to the processing of emotions in a variety of social contexts (Kurth et al., 2010). Recently, the anterior insula is being considered as a hub to the ventral attention network system where it plays an important role in attention control and saliency processing (Menon, Uddin, 2010).

Our results regarding functional connectivity analyses revealed that the strength of functional connectivity (in post- vs. pre-task) was significantly increased between the left AI and the IFG. Furthermore, while the pre-task functional connectivity did not vary between those areas across participants, there was a positive correlation between the changes in functional connectivity between the left IFG and AI and the difference in reaction time in response to in-group vs. rival mismatch pairs. Nevertheless, this finding should be interpreted with caution as our sample was small (Yarkoni, 2009).

The findings regarding the IFG and the AI suggest that increased functional connectivity within the fronto-insula network could be related to an enhanced attention, to the pairing of the rival and in-group relevant stimulus. Again, this might indicate to some sort of social stroop effect. Previous studies have reported evidence for functional

connectivity between the IFG and the AI in the context of social relevance. For example, using Granger Causality, it has been shown that activity in the IFG was associated with responses in the AI to emotionally salient stimuli (Jabbi, & Keysers, 2008). Recent studies of the functional synchronization between the AI and the IFG further indicate that coherent co-activation of these areas arises across a wide variety of contexts, consistent with the two regions acting as a "fronto-insula junction" in social and emotional processing (Craig, 2009).

We also found that the functional connectivity between the left AI and the left DLPFC decreased after the task was performed compared to before the task was performed. This finding might imply that throughout the task, participants' responses became more automatic and therefore task performance did not require as much attentional control as required to start with. Previous studies relate the functional coupling between the AI and the DLPFC to memory retrieval (Assaf et al., 2006), which is consistent with our interpretation of the development of automaticity in the retrieval of shape/badge associations and with reduced effort being required as practice increased.

The positive versus negative functional connectivity between the AI and (i) the IFG and (ii) the DLPFC respectively, can also be explained in relation to attention. Recent models of attention posit that the AI and IFG work as a part of the cingulo-opercular attention system which helps maintain attention throughout a task. In contrast the DLPFC operates as a part of a fronto-parietal attention system, which plays a role in rapid adaptive control (Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008). Note that the need for rapid adaptive control may decrease as the performance in the task becomes more automatic.

There are several issues concerning the present analyses that might deserve extra attention. First, the comparison between in-group and rival was complicated by a

potential confound of the effect of emotions on the performance in the task. This is particularly important in a context such as sport rivalry where the outgroup (in general) is associated with negative emotions (Amodio, 2014). Therefore, we need to investigate how emotions, especially negative emotions driven by viewing rival badge affect participants' performance in the task as well as their brain responses. This could be addressed in the future studies.

The second issue concerns participants' behavioural performance in the social association task. Based on the participants' longer reaction time on the task, the rival pairs across both match and mismatch trials seem to be more difficult to respond to. Usually, in cognitive neuroscience experiments the conditions with longer RT tend to be assumed as more difficult. However, longer RT could also reflect the prolonged engagement with the stimulus (see for example, Petersen & Posner, 2012). While this could be true for most of the cases, for a bitter sport rivalry context, longer RT might not necessarily reflect the higher difficulty or enhanced engagement with the stimuli. Longer RT especially when it comes to the traditional rival team could reflect the negative emotions associated with viewing the team that the participants dislike which could in turn slow down the responses when the rival badge was presented (or paired with in-group shape). Therefore, we suggest that the future studies try to investigate how the task difficulty and visual engagement differentially affects the brain activity in the context of sport rivalry.

In conclusion, our findings suggest that different areas in the ventral and dorsal attention networks are functionally coupled in order to respond to socially salient stimuli, and that there is rapid modulation of neural connectivity between these regions through learning of new in-group and outgroup associations. Furthermore, alterations in resting

state functional connectivity between AI-IFG might explain one of the possible mechanisms underlying the neural substrates of in-group bias.

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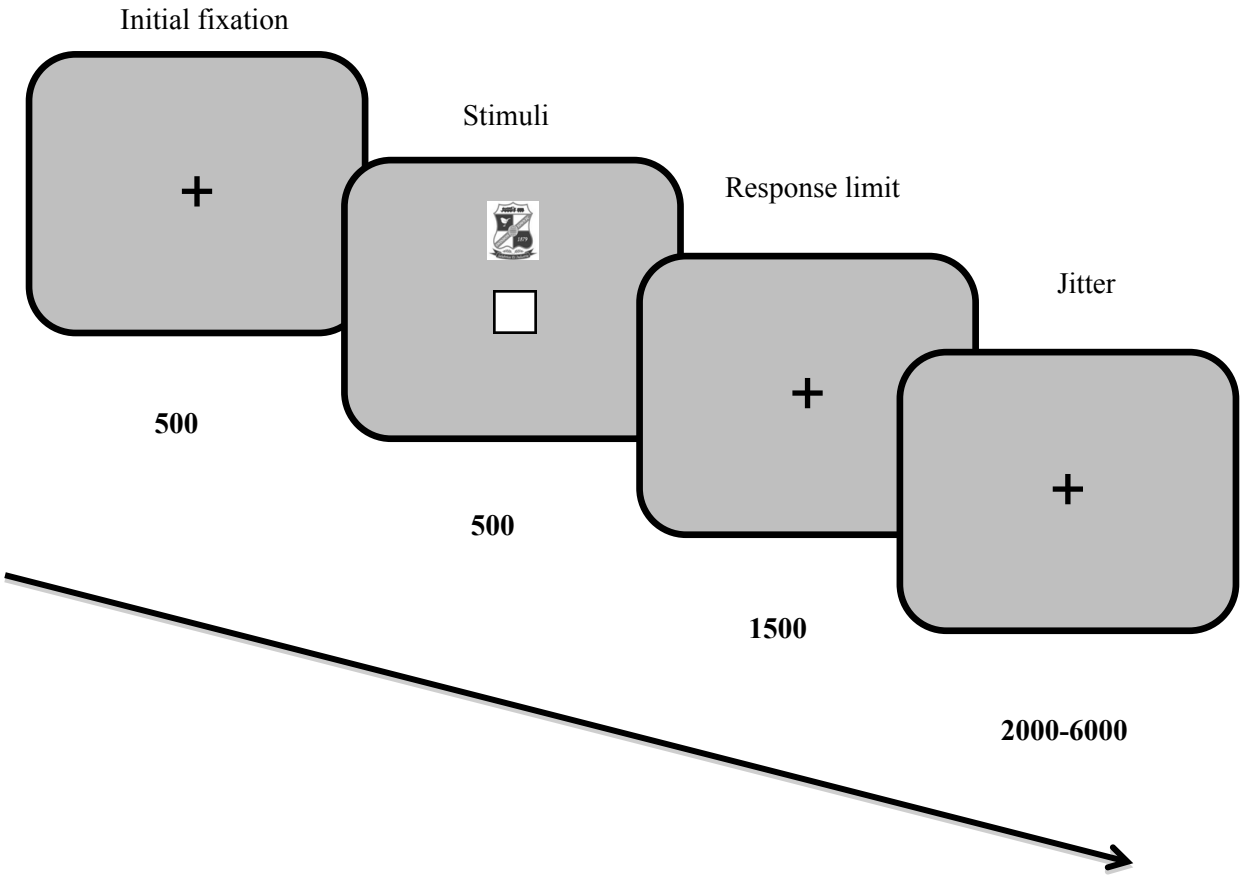
Initial fixation
Stimuli
Response limit
Jitter
500
500
1500
2000-6000

Figure 1.

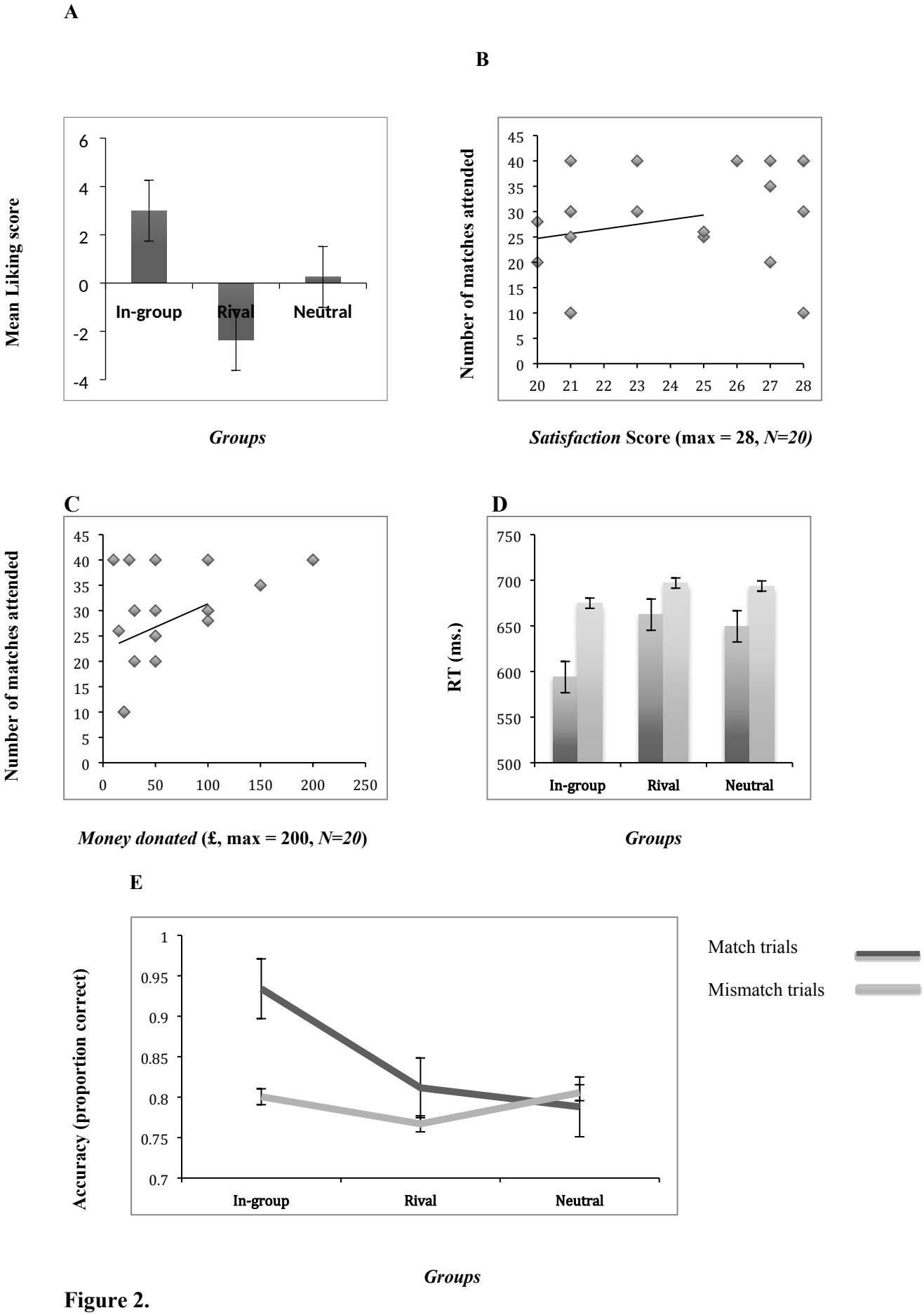
A
B
Mean Liking score
6
4
2
0
-2
-4
In-group
Rival
Neutral
Groups
Number of matches attended
45
40
35
30
25
20
15
10
5
0
20 21 22 23 24 25 26 27 28
Satisfaction Score (max = 28, N=20)
C
D
Number of matches attended
0 50 100 150 200 250
Money donated (£, max = 200, N=20)
RT (ms.)
750
700
650
600
550
500
In-group
Rival
Neutral
Groups
E
Accuracy (proportion correct)
1
0.95
0.9
0.85
0.8
0.75
0.7
In-group
Rival
Neutral
Groups
Match trials
Mismatch trials

Figure 2.

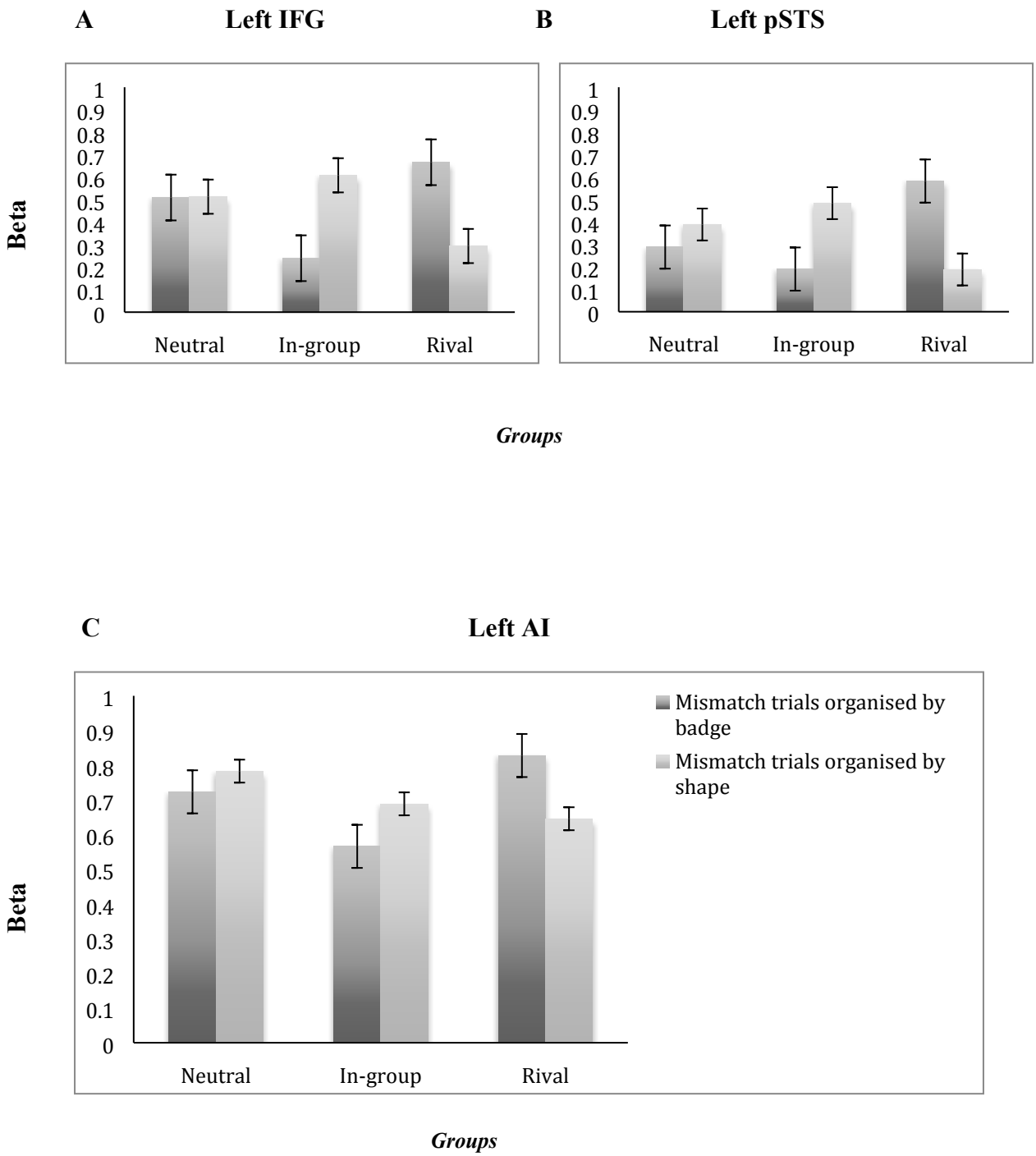
A
Left IFG
B
Left pSTS
Beta
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Neutral
In-group
Rival
Groups
C
Left AI
Mismatch trials organised by badge
Mismatch trials organised by shape

Figure 3.

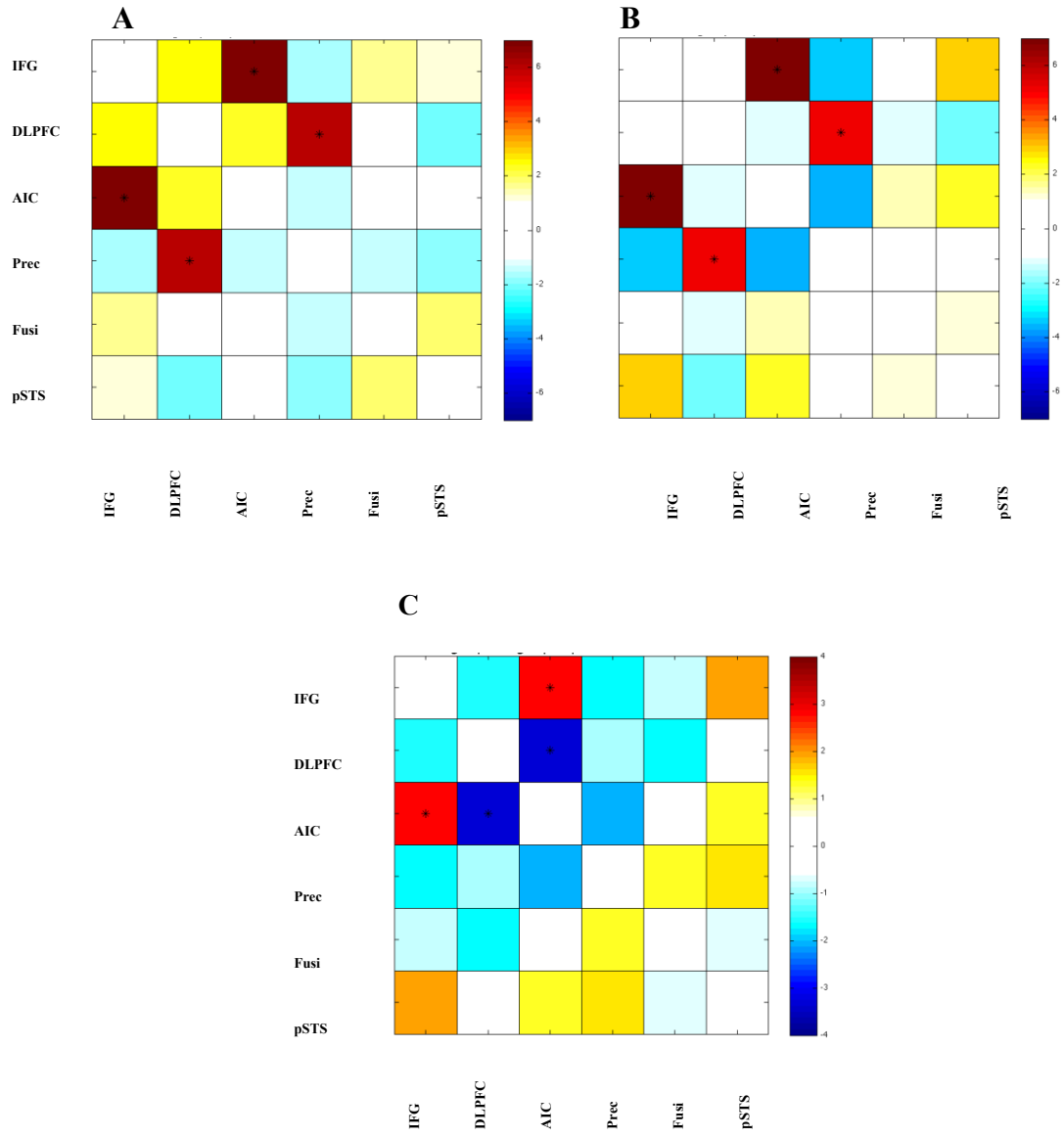
A
B
C
D
IFG
DLPFC
AIC
Prec
Fusi
pSTS
In-group bias (RT on rival mismatch– in-group mismatch)
The strength of post-task functional connectivity based on t-value

Figure 4.

Figure captions

Figure 1. Schematic representation of the task used in the fMRI Experiment.

Figure 2. Results regarding the ratings and behavioural performance in the task

(A) Mean rated liking score (based on 7-point scale) as a function of group relevance. The 7-point scale was from -3 (strongly dislike) to 3 (strongly like). Error bars represent standard error.

(B) Positive correlations between mean number of matches attended per season (Y axis) and in-group satisfaction score

(C) Positive correlations between mean number of matches attended per year (Y axis) and money donated (£) to support the in-group team.

(D) Mean reaction time (ms.) for the correct responses across the match (dark grey) and mismatch (light grey) pairs as the function of group relevance. Error bars represent standard error.

(E) Mean accuracy (proportion correct) for the match (dark grey) and mismatch (light grey) pairs as the function of group relevance. Error bars represent standard error.

Figure 3. Parameter estimation (beta-values) in ROIs analyses.

(A) the left IFG, **(B)** the left pSTS and **(C)** the left AI for the mismatch trials organised by badge (dark grey) and by shape (light grey) as a function of group relevance. IFG: inferior frontal gyrus, pSTS: posterior superior temporal sulcus, AI: anterior insula.

Figure 4. Results regarding functional connectivity analyses.

(A) The strength of pre-task functional connectivity. (Random effect analyses, FDR corrected, $p < .001$).

(B) The strength of post-task functional connectivity (Random effect analyses, FDR corrected, $p < .001$).

(C) Altered functional connectivity comparing post- vs. pre-task sequences in the seeds of interest. (uncorrected for multiple comparison in the map, $p<.05$).

(D) Positive correlation between the changes in the strength of functional connectivity in post- versus pre-task for AI/ IFG and the magnitude of in-group bias based on the RT difference for in-group vs. rival mismatch pairs (N=20, max satisfaction score = 28).

Highlights

- fMRI and task-free resting states before and after the task were combined.
- Post-task FC between the LAI and LIFG was increased.
- Post-task FC between the LAI and LDLPFC was decreased.
- Changes in FC between the LAI and LIFG positively correlated with in-group bias.