

Individual differences in structural and functional connectivity predict speed of emotion discrimination

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Highlights

- Discrimination speed of angry and fearful faces related to separate networks.
- Angry faces are discriminated faster by extended emotional face processing network.
- Fearful faces are discriminated faster by cortical visual-attentional regions.
- Discrimination speed of angry but not fearful faces associated with right amygdala.
- Integrity of inferior longitudinal fasciculus improves threat discrimination speed.

Abstract

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2 In social interactions, individuals who are slower at differentiating between facial
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4 expressions signalling direct and indirect threat might be at a serious disadvantage.
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6 However, the neurobiological underpinnings of individual differences in face
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8 processing are not yet fully understood. The aim of this study was to use multimodal
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10 neuroimaging to investigate how the speed of emotion recognition is related to the
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12 structural and functional connectivity underlying the differentiation of direct and
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14 indirect threat displays. Our results demonstrate that individuals, who are faster at
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16 discriminating angry faces, engaged areas of the extended emotional system more
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18 strongly than individuals with slower reaction times, showed higher white matter
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20 integrity in the inferior longitudinal fasciculus, as well as stronger functional
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22 connectivity with the right amygdala. In contrast, individuals, who were faster at
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24 discriminating fearful faces, engaged visual-attentional regions outside of the face
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26 processing network more strongly than individuals with slower reaction times,
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28 showed higher white matter integrity in the inferior longitudinal fasciculus, as well as
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30 reduced functional connectivity with the right amygdala. Our findings suggest that the
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32 high survival value of rapid and appropriate responses to threat has defined but
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34 separate neurobiological correlates for angry and fearful facial expressions.
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46 **Keywords:** emotion discrimination; structural-functional connectivity; individual
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1. Introduction

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Rapid and accurate discrimination of facial expressions of emotion is important for preparing adequate and timely responses in social interactions (Cizek & Kalaska, 2010). Rapid discrimination is particularly important for facial expressions displaying anger and fear, as these emotions signal direct and indirect threat respectively, which might require an immediate fight-or-flight response (Bannerman et al., 2009; Hansen & Hansen, 1988; Lo & Cheng, 2015; Whalen et al., 2001). Previous research has shown that the ability to rapidly discriminate between emotional facial expressions signalling threat depends on the core face-processing network, including inferior occipital gyrus, superior temporal sulcus, and fusiform gyrus, as well as the extended emotional system centered on the amygdala (Haxby et al. 2002; Rossion et al., 2003; Gobbini & Haxby, 2007). During the conscious recognition of threatening emotional facial expressions, the core network and the extended emotional system interact through bidirectional functional connections between the amygdala and the fusiform gyrus (Herrington et al., 2011; Wang et al., 2016). Functional connectivity between fusiform gyrus and amygdala, together with the ability to discriminate emotions depend on white matter pathways within the inferior longitudinal fasciculus (Kleinhans et al., 2008; Koldewyn et al., 2014). This structural-functional relationship allows the amygdala to exert top-down control on the ventral visual pathway during the perception of threat-signalling facial expressions (Amaral, Behniea & Kelly, 2003; Villeumier et al., 2003; De Gelder et al., 2014). Thus, this evidence suggests that rapid discrimination of threat-related emotional facial expressions crucially depends on the functional and structural connectivity between the amygdala and fusiform gyrus and that individuals with less efficient structural and functional connectivity may be at a disadvantage in threat-

1 related social interactions. However, to date, no study has investigated whether the
2 functional and structural connectivity between the amygdala and fusiform gyrus
3 affects the speed of emotion discrimination in healthy adults.
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7 The objective of this study was to investigate whether individual differences in
8 structural integrity and functional connectivity between the core and extended
9 emotional face-processing networks would predict the speed of conscious emotion
10 discrimination for angry and fearful facial expressions. In particular, we were
11 interested in the three-way **relation** between structural connectivity, functional
12 connectivity, and behaviour during an emotion discrimination task that required
13 participants to match facial expressions of fear or anger. As an indicator of structural
14 connectivity, we assessed the white matter integrity of the inferior longitudinal
15 fasciculus (ILF), which constitutes the major white matter pathway along the ventral
16 visual processing stream, mediating the interactions between the amygdala and the
17 fusiform gyrus during face processing (Catani et al., 2003; Thomas et al., 2009). As
18 an indicator of functional connectivity, we used a seed-based approach and covaried
19 functional activity within the amygdala with task-related activity across the whole
20 brain. As an indicator of behaviour, we measured reaction times of emotion
21 discrimination. Based on previous studies, which show that angry and fearful faces
22 are identified equally fast and that processing of both emotions engages the core and
23 extended face-processing networks (De Sonneville et al., 2002; Whalen et al., 2001),
24 we hypothesized that, as a group, participants would (i) be equally fast to match angry
25 and fearful faces and (ii) engage the core and extended face processing networks for
26 both facial expressions. Based on the assumption that the discrimination of different
27 emotional expressions requires the interaction between the amygdala and fusiform
28 gyrus (Herrington et al., 2011; Wang et al., 2016), we further hypothesized that (iii)
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1 for both angry and fearful facial expressions, individuals who discriminate emotions
2 more rapidly would also have better white matter integrity in the ILF and increased
3 functional connectivity within and between the core and extended face-processing
4 networks. More specifically, we hypothesized that shorter reaction times should
5 correlate with higher FA values as well as connectivity values in the face processing
6 network.
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17 **2. Methods**

18 *2.1 Participants*

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22 28 right-handed adults (14 females, mean age = 26.3 years, age range = 21-34
23 years) with normal or corrected to normal vision gave written consent to take part in
24 the experiment, which was approved by the Human Ethics Research Committee of the
25 University of Queensland. All participants were screened for neuropsychological
26 disorders, brain damage, and substance abuse. Images were acquired with a Siemens
27 Magnetom Trio 3T (Siemens Healthcare, Erlangen, Germany) and a standard 32-
28 channel head coil at the Centre for Advanced Imaging, University of Queensland.
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41 *2.2 Experimental Procedure*

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44 Participants took part in an emotion-matching task adapted from the paradigm
45 described in Hariri et al. (2000). During each trial, three images were presented, one
46 in the top and two in the bottom half of the screen using Presentation software
47 (Neurobehavioral Systems, Inc.). One of the bottom two images was identical to the
48 top image and participants were asked to identify the image in the bottom half of the
49 screen that matched the top image by pressing the one of two buttons associated with
50 the left and right image. Images either showed black elliptical shapes angled at 45° or
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315° (shapes condition) or facial expressions with a target of angry (angry condition) or fearful facial expressions (fearful condition). During presentation of facial expressions, all pictures were of the same model and always included one fearful and one angry facial expression presented in the bottom row, which makes the two facial expression conditions directly comparable. Reaction times were measured and data from individual trials was removed from the behavioural analysis if they constituted outliers, i.e., a reaction time shorter than 350 ms or longer than 1800 ms.

Image stimuli consisted of 24 pictures selected from the Radboud Faces Database (<http://www.socsci.ru.nl:8180/RaFD2/RaFD>). In each picture, a trained model (young adult Caucasian males and females) displayed either a fearful or an angry facial expression with direct gaze (Langner et al., 2010). Control stimuli consisted of black ellipses angled at 45° or 315° generated by Presentation software. Images were presented in 6 blocks (3 blocks of shapes, 3 blocks of faces), each containing 6 trials. The presentation order of blocks was randomized. At the beginning of each block, an instruction was presented for 3s to either “match the faces” or to “match the shapes”. In each trial, the images were presented for 2s followed by a fixation cross for 1s.

Due to a technical error, the behavioural accuracy of the participants’ responses was not recorded. Observations of participants’ responses during the task suggested that behavioural accuracy was at ceiling and that accuracy would not be an important factor in assessing the **relation** between behaviour, structure, and function. To confirm this observation, we subsequently tested the same paradigm behaviourally in a separate sample of 28 young, right-handed adults (mean age = 22 years, age range = 18-30 years, 19 females). As predicted, participants’ accuracies showed a ceiling effect for each of the three stimulus types: angry faces group mean score = 0.96, SD =

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0.04; fearful faces group mean score = 1.0, SD = 0.0; and shapes group mean score = 0.94, SD = 0.09. To ensure comparability between the two groups, we further compared their reaction times. A 2 x 3 mixed-design ANOVA of the dependent variable reaction time with a fixed effects factor group (first, second) and a random effects factor stimulus (angry, fearful, shapes) yielded a significant factor of group ($F(1) = 40.167$, $p < 0.001$) and a significant factor of stimulus ($F(2) = 20.603$, $p < 0.001$), but no interaction between factors. Using only data from the second group, two-sided t-tests of the reaction times to different stimulus types showed significantly faster responses to shapes than to angry and fearful facial expressions (both $t(27) > 6.4$, both $p < 0.001$) but not between facial expressions ($t(27) = 0.5$, $p = 0.7$). These results replicate the results reported below for the first group although participants in the second group were overall faster across all stimulus types (significant main effect of the factor group). This group difference can be attributed to the different testing conditions because the first group was tested in the MRI whereas the second group was tested in a behavioural laboratory. Taken together, these results confirm that reaction time but not accuracy should be considered an important factor when investigating the **relation** between behaviour, structure, and function during the emotion-matching task.

2.3 Image Acquisition

For each participant, a T1-weighted volumetric anatomical MRI was acquired with the following parameters: 176 slices sagittal acquisition MP2RAGE; 1mm^3 isotropic volume; repetition time (TR) = 4000 msec; echo time (TE) = 2.89 msec; flip angle = 6° ; FOV = 256 mm, GRAPPA acceleration factor = 3. Functional images were acquired using a T2*-weighted echo-planar image pulse sequence with the

1 following parameters: 45 slices; voxel size = 2.5 x 2.5 x 2.7 mm; TR = 3000 msec;
2 TE = 30 msec; FOV = 192 mm; flip angle = 90°. Diffusion-weighted images with a
3 high angular resolution (HARDI) were acquired for each participant using a fast echo-
4 planar sequence with the following parameters: b1-value = 3000 s/mm²; 64 gradient
5 directions; TR = 8600 msec; TE = 109 msec; FOV = 240 mm; 60 slices; voxel size =
6 2.3 mm isotropic; GRAPPA acceleration factor = 2.
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17 *2.4 fMRI Preprocessing & Whole-Brain Analysis*

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19 Brain activation was assessed using the blood oxygenation level dependent
20 (BOLD) effect (Ogawa et al., 1990) with optimal contrast. For functional analysis,
21 T2*-weighted images were preprocessed with Statistical Parametric Mapping
22 software (SPM8; <http://www.fil.ion.ucl.ac.uk/spm>). Images were realigned to a mean
23 image to correct for head motion and then spatially normalized into standard
24 stereotaxic space with voxel size of 2 mm³, using the Montreal Neurological Institute
25 (MNI) template. Head movement and rotation did not exceed 1 mm or 1.5° and no
26 dataset had to be excluded from the analysis. Finally, the functional images were
27 spatially smoothed with a 6-mm full width half maximum Gaussian kernel.
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41 Following preprocessing, images were submitted to whole-brain analysis
42 using PLS software (PLS, <http://www.rotman-baycrest.on.ca/index.php?section=84>).
43 PLS analysis proceeds in several steps (McIntosh et al., 1996, 2004; Krishnan et al.,
44 2011). First, data from individual trials and participants are sorted by condition and
45 collated into a single data matrix and a second matrix containing task design (for task-
46 PLS) as well as covariates of interest (seed-PLS) is created. Second, the data and
47 covariate matrices are mean-centered and normalized. Third, a covariance matrix is
48 created from the dot product of the data and covariates matrices. Fourth, PLS uses
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1 singular value decomposition - a form of principal components analysis – to identify
2 brain activity patterns related to task conditions (task PLS) and task conditions as well
3 as seed values (seed PLS). Since PLS analyzes the data in a single analytical step, no
4 corrections for multiple comparisons are necessary. Singular value decomposition
5 yields latent variables that relate to the largest dimensions of variation within the data.
6 Each latent variable consist of a pattern of brain activity, a singular value, and a
7 matrix of loadings that indicate how each pattern relates to the task design and the
8 seed values. Fifth, PLS assesses the reliability of the brain activity patterns at each
9 voxel using a bootstrap estimation of the standard error with 100 iterations. All brain
10 activity patterns were thresholded at a bootstrap ratio of 2 as this equates to a p-value
11 of < 0.05. Sixth, PLS calculates a brain score for each experimental condition and
12 each participant, which indicates how strong a pattern is represented in the
13 experimental sample (McIntosh et al., 2004). Brain scores therefore represent
14 individual differences.

2.5 White Matter Analysis

36 Structural connectivity was assessed using MRtrix3 software
37 (<https://github.com/MRtrix3/>) and tools from the FMRIB Software Library (FSL
38 5.0.6; <http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/>). HARDI images were first corrected for
39 motion and eddy current artefacts using *eddy_correct*, after which vectors were
40 reoriented using *fdt_rotate_bvecs* (Graham, Drobnyak & Zhang, 2016). Then, a brain
41 mask was created from the corrected b0 image using *fsROI* and skull-stripped using
42 *bet* (Smith, 2002). Tensors were fitted using *dwi2tensor*, and fractional anisotropy
43 (FA) values were computed for each voxel using *tensor2metric* (Veraart et al., 2013).
44 Next, the DWI response function was estimated using *dwi2response* and the fiber

1 orientation distribution (FOD), which was derived using constrained spherical
2 deconvolution (CSD) with harmonic order 8 as implemented in *dwi2fod* (Tournier et
3 al., 2004, 2007).
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7 For tractography, each individual's T1-weighted image was first segmented
8 using FSL's *first* to derive individual masks for gray matter and cerebro-spinal fluid
9 (CSF; Patenaude et al., 2011). Then, masks for left and right amygdala, as well as left
10 and right fusiform gyrus were defined as anatomical regions of interest using the AAL
11 atlas and masked using individual gray matter masks (Tzourio-Mazoyer et al., 2002).
12 All masks were transformed into individual diffusion space using *flirt* (Jenkinson &
13 Smith, 2001; Jenkinson et al., 2002). Unidirectional probabilistic streamlines between
14 amygdala seed masks and fusiform gyrus inclusion masks were computed for each
15 hemisphere using *tckgen*, the FODs derived from CSD, an exclusion mask derived
16 from each individual's CSF, and the iFOD2 algorithm with a step size of 1.15 and a
17 cut-off of 0.15 (Tournier et al., 2010, 2012). After visual inspection, streamlines were
18 converted to track-density images with *tckmap*, thresholded using *mrthreshold*,
19 binarized with *fsmaths*, and used as masks to extract the mean values for each
20 individual from the FA images using *fslstats* (Calamante et al., 2010).
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44 *2.6 Structure-Function-Behaviour Analysis*

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46 To assess the **relation** between reaction time, ILF FA values, and amygdala
47 functional connectivity, average time-courses of seed regions in left and right dorsal
48 amygdala were first extracted from each individual using a 5-mm sphere centered at
49 MNI coordinates [-20 -8 -12] and [22 -6 -12]. The coordinates were chosen based on
50 a priori anatomical information about the location of the left and right amygdala as
51 well as the results of the whole-brain analysis, where the coordinates represent peak
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1 amygdala activations differentiating the processing of fearful and angry faces from
2 shapes. Then, the mean reaction times, mean ILF FA values, and functional seed
3 values were correlated with each participant's whole-brain activity and submitted to
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7 **seed** PLS analysis (Krishnan et al., 2011). **In seed** PLS analysis, the results **display** the
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9 Pearson product-moment correlation coefficient between brain scores of the LV and
10 the reaction times, ILF FA values, and amygdala functional seed values for each
11 condition (Marstaller et al., 2015). As a consequence, these correlations reflect
12 individual differences in the three-way **relation between structure, function, and**
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19 **behavior.**
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24 **3. Results**

25 *3.1 Reaction times*

26 Repeated measures two-sided t-tests revealed that participants responded
27 significantly faster to shapes (mean RT = 899.14 ms, SD = 163.89 ms) than angry
28 (mean RT = 1096.11 ms, SD = 170.78 ms; $t(27) = 6.3$, $p < 0.001$) and fearful faces
29 (mean RT = 1065.88 ms, SD = 153.61 ms; $t(27) = 5.8$, $p < 0.001$). There was no
30 significant difference in reaction times between angry and fearful faces ($t(27) = 1.3$, p
31 = 0.21; see Figure 1A). Reaction times for angry and fearful faces were highly
32 correlated ($r = 0.7$).
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48 *3.2 ILF white-matter integrity*

49 Group-mean FA-values were 0.42 (SD = 0.03) for the left and 0.41 (SD =
50 0.06) for the right ILF. A two-sided repeated measures t-test showed no significant
51 differences between the two hemispheres ($t(27) = 1.5$, $p = 0.13$; see Figure 1B).
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(INSERT FIGURE 1 HERE)

3.3 *Whole-brain task-related functional activity*

PLS analysis resulted in two significant whole-brain activity patterns. The first pattern of activity differentiated the control condition (shapes) from face presentations and demonstrated a shared activation pattern for angry and fearful expressions. Angry and fearful faces were associated with increased activity in the core and extended emotional face processing system, including bilateral inferior occipital gyrus, fusiform gyrus, and dorsal amygdala (see cool colours in Figure 2). Presentation of shapes resulted in greater activity in posterior parietal cortices (see warm colours in Figure 2; see Table 1).

(INSERT FIGURE 2 HERE)

The second significant pattern of activity differentiated angry from fearful faces. For angry faces, the pattern showed increased activity in the right orbitofrontal cortex, left caudate nucleus, and middle frontal cortex, as well as in areas commonly associated with semantic processing (right hippocampus and middle temporal gyrus; Binder et al., 2009), salience detection (anterior cingulate cortex; Critchley, 2005), and bottom-up attention (right ventrolateral prefrontal cortex and right supramarginal gyrus; Fox et al., 2006; see warm colours in Figure 3). For fearful faces, the pattern showed increased activity in the right ventral amygdala, fusiform gyrus, and left pallidum (see cool colours in Figure 3; see Table 2).

(INSERT FIGURE 3 HERE)

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5 *3.4 Three-way relation between reaction time, ILF integrity, and amygdala functional*
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7 *connectivity*

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10 PLS analysis revealed two significant whole-brain patterns of amygdala
11 functional connectivity that showed a different relation between functional
12 connectivity, behaviour and ILF white matter integrity for angry and fearful faces.
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14 During perception of angry facial expressions, a set of limbic-temporal regions was
15 functionally connected to the right ($r = 0.37$) but not the left amygdala ($r = -0.028$).
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17 This functional network was negatively correlated with reaction times ($r = -0.72$), but
18 positively correlated with FA values of the left ($r = 0.45$) and right ILF ($r = 0.37$) and
19 included bilateral hippocampus, brainstem, and the right temporal pole (see Figure 4).
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21 These results therefore show that individuals, who were faster at identifying angry
22 faces, engaged this extended amygdala network more strongly, had better
23 connectivity with the right amygdala, and a higher ILF white matter integrity
24 bilaterally. Individual differences in the three-way relation between behaviour, white
25 matter integrity, and functional connectivity are displayed as scatter plots that indicate
26 how much each factor correlated with the depicted pattern of activity across the
27 sample (see Figure 4).
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1 negatively correlated with reaction time ($r = -0.37$) but positively with FA values of
2 the left ($r = 0.3$) and right ILF ($r = 0.51$) and included bilateral lingual gyrus,
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4 precuneus, middle and superior frontal gyrus, supramarginal gyrus, and precentral
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6 gyrus meaning that individuals, who were faster at differentiating fearful faces,
7
8 engaged this fronto-parietal-occipital network more strongly, had lower connectivity
9
10 with the right amygdala, and a higher ILF white matter integrity bilaterally. Individual
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12 differences in the three-way **relation** between behaviour, white matter integrity, and
13
14 functional connectivity are displayed as scatter plots that indicate how much each
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16 factor correlated with the depicted pattern of activity across the sample (see Figure 5).
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24 (INSERT FIGURE 5 HERE)
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29 **5. Discussion**

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31 In social interactions, individuals who are slower at distinguishing between
32
33 facial expressions signalling direct and indirect threat might be at a serious
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35 disadvantage. However, the neurobiological underpinnings of individual differences
36
37 in face processing are not yet fully understood. The aim of this study was to
38
39 investigate how the speed of emotion recognition is related to the structural and
40
41 functional connectivity underlying the differentiation of direct and indirect threat
42
43 displays. The analysis of the three-way **relation** between behaviour, structure, and
44
45 function underlying the core and extended systems for angry and fearful face
46
47 processing revealed behaviourally relevant individual differences. Individuals who
48
49 were faster at identifying angry faces engaged areas of the extended emotional system
50
51 more strongly than individuals with slower reaction times. These faster individuals
52
53 further showed higher white matter integrity in the ILF and stronger functional
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1 connectivity with the right amygdala, suggesting that an efficient structural and
2 functional connectivity between the core and extended emotional systems is crucial
3 for the rapid processing of facial expressions signalling direct threat. This finding
4 implicates that the high survival value of rapid and appropriate responses to direct
5 threat has a defined neurobiological correlate.
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11 With respect to fearful faces that signal indirect threat, our results showed that
12 individuals who were faster at discriminating fearful faces also had more intact white
13 matter in the ILF but less functional connectivity between the face processing
14 network and the amygdala. Those faster individuals engaged more regions outside of
15 the face processing network related to attention and visual processing, suggesting that
16 the processing speed of facial expressions signalling indirect threat profits from the
17 recruitment of additional visual-attentional systems, which are engaged in searching
18 for novel cues that help reduce the ambiguity associated with indirect threat
19 expressions (Whalen et al., 2001; Phelps, Ling, & Carrasco, 2005). In contrast to
20 direct threat, the rapid recognition of indirect threat, therefore, seems to depend less
21 on the cortical face-processing network and instead might rely more on a subcortical
22 pathway (Villeumier et al., 2003). In addition, individual differences in the rapid
23 recognition of indirect threat displays seem to directly translate into the ability to
24 gather additional information that reduces the ambiguity associated with fearful facial
25 expressions, and individuals who rapidly reduce ambiguity might profit from higher
26 white matter integrity in the ILF along the ventral visual stream.
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51 The whole-brain results confirm previous findings by demonstrating the
52 engagement of the core face-processing network, which consists of inferior occipital
53 and fusiform gyrus and the extended emotional system centered around the amygdala,
54 for both angry and fearful faces (Adolphs, 2002; Haxby et al. 2002; LaBar et al.,
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2003; Gobbini & Haxby, 2007). The results further show that the dorsal amygdala and fusiform gyrus are engaged during the perception of both angry and fearful faces, which is in accordance with previous findings demonstrating increased vigilance during perception of threat (Davis & Whalen, 2001; Williams et al., 2001). The absence of activity in the superior temporal sulcus and premotor cortices in our data is possibly related to the static stimuli used in this experiment (Grèzes, Pichon & de Gelder, 2007; Said, Haxby & Todorov, 2011). Perception of angry faces additionally activated cortical regions associated with evaluative processing, such as the salience (Menon & Uddin, 2010; Pichon, de Gelder & Grèzes, 2012) and ventral attention networks (Corbetta & Shulman, 2002), as well as regions associated with memory processing (Haxby et al., 1996; Frey & Petrides, 2003; Tsukiura & Cabeza, 2008). This finding suggests that angry faces might engage cortical regions related to evaluative, contextual processing more strongly than fearful faces, perhaps because anger directs attention towards the angry individual, whereas fear directs attention towards the ambiguous cause of the threat (Grosbras & Paus, 2006; Pichon, de Gelder & Grèzes, 2009). Fearful faces additionally engaged the amygdala and fusiform gyrus, which is in line with previous findings and suggests increased processing of fearful compared to angry facial expressions within regions of the core and extended emotional faces processing systems (Whalen et al., 2001). Perception of fearful faces further engaged the left globus pallidum, which might be related to the initiation of a fight-or-flight response (Korzeniewska, Kasicki & Zagrodzka, 1997; Grèzes & Dezeccache, 2014).

In sum, our results extend our current knowledge about the networks involved in the processing of emotional facial expressions by demonstrating that individual differences in the structural and functional connectivity within and between the core

1 and extended emotional face-processing systems affect the speed at which emotional
2 faces are discriminated. The associated adaptive value of efficient structural and
3 functional connectivity between the core and extended emotional face-processing
4 systems points towards a neurobiological cause for individual differences in social
5 interactions. As a consequence, genetic and environmental factors that influence the
6 development and age-related degeneration of structural and functional connectivity
7 underlying emotional face discrimination might determine an individual's success in
8 responding to threat in social interactions and hence impart a high survival value
9 (Cohen Kadosh, 2011; Scherf et al., 2014; Shaw et al., 2016).
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Figure Captions:

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5 Figure 1: Behaviour and white matter integrity. A: Mean reaction times (+/- SEM)
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7 show significantly slower responses when matching angry and fearful facial
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9 expressions than when matching shapes. B: Mean fractional anisotropy (FA) values
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11 (+/- SEM) for left and right inferior longitudinal fasciculus (left). Tractography results
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13 from a representative subject (right).
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19 Figure 2: Whole-brain activity differentiating faces and shapes. Warm colours show
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21 functional activity in posterior parietal cortices during processing of shapes. Cool
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23 colours depict functional activity in the core and extended emotional face processing
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25 regions, including inferior occipital gyrus, fusiform gyrus, and dorsal amygdala,
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27 during processing of angry and fearful facial expressions.
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33 Figure 3: Whole-brain activity contrasting angry and fearful facial expressions. Warm
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35 colours show functional activity related to angry facial expressions. Cool colours
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37 depict functional activity related to fearful facial expressions.
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43 Figure 4: Individual differences in the three-way **relation** between behaviour,
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45 functional connectivity, and ILF white matter integrity for angry faces. Left: Whole-
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47 brain patterns showing functional connectivity with the right amygdala negatively
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49 correlated with reaction times and positively with ILF FA values, including
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51 hippocampus, brainstem, and the right temporal pole. Right: Scatter plots demonstrate
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53 correlations between individual PLS brain scores (indicating how strongly each
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55 individual expressed the whole-brain pattern) on the ordinate and the covariates
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1 reaction time (in msec), left and right amygdala functional seeds (in % signal change),
2 as well as mean FA values of left and right ILF (in arbitrary units) on the abscissa.
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7 Figure 5: Three-way **relation** between behaviour, functional connectivity, and ILF
8 white matter integrity for fearful faces. Left: Whole-brain patterns showing functional
9 connectivity with the right amygdala correlated with reaction times and ILF FA
10 values, including bilateral lingual gyrus, precuneus, middle and superior frontal gyrus,
11 supramarginal gyrus, and precentral gyrus. Right: Scatter plots demonstrate
12 correlations between individual PLS brain scores (indicating how strongly each
13 individual expressed the whole-brain pattern) on the ordinate and the covariates
14 reaction time (in msec), left and right amygdala functional seeds (in % signal change),
15 as well as mean FA values of left and right ILF (in arbitrary units) on the abscissa.
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Figure 1
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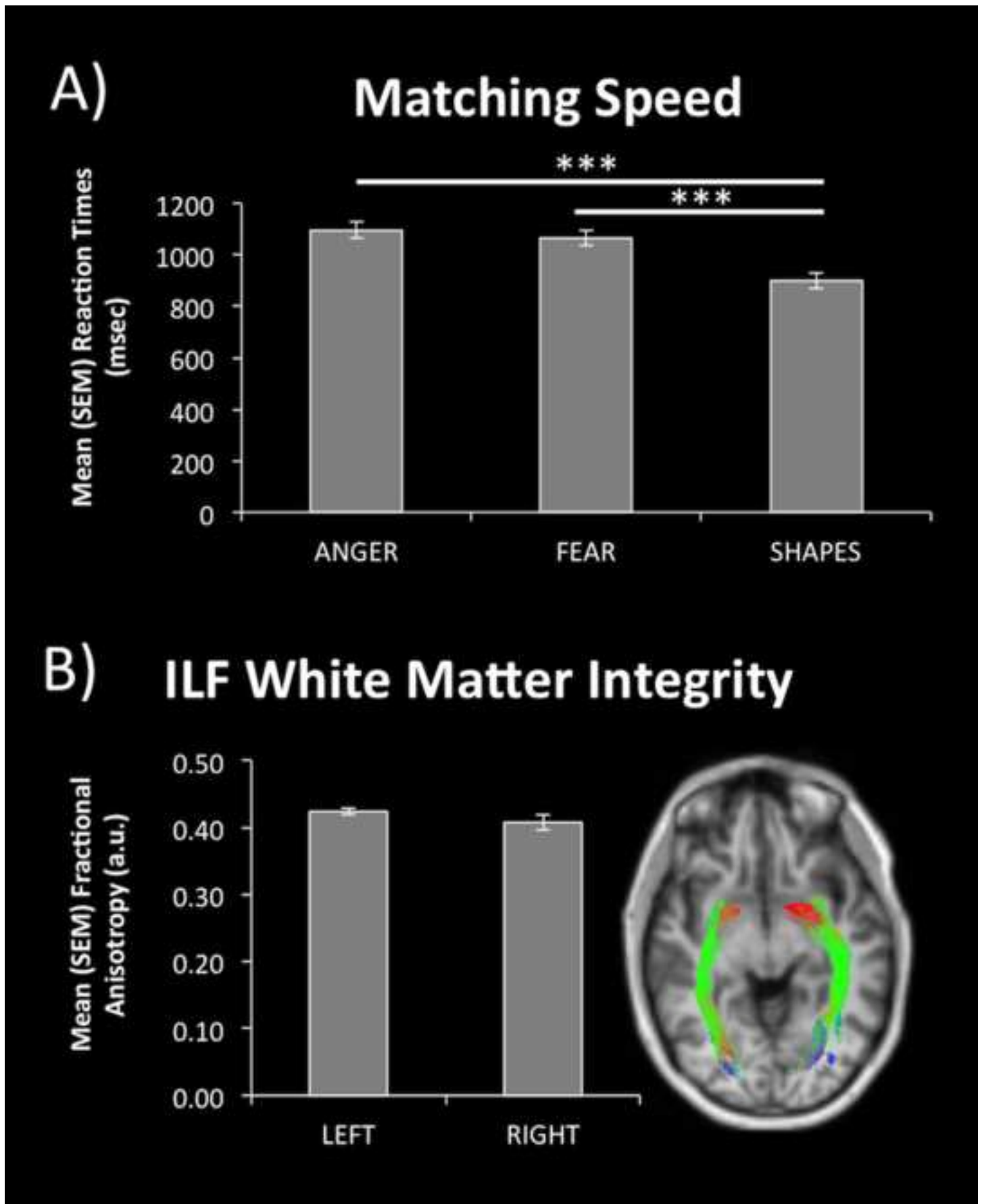


Figure 2
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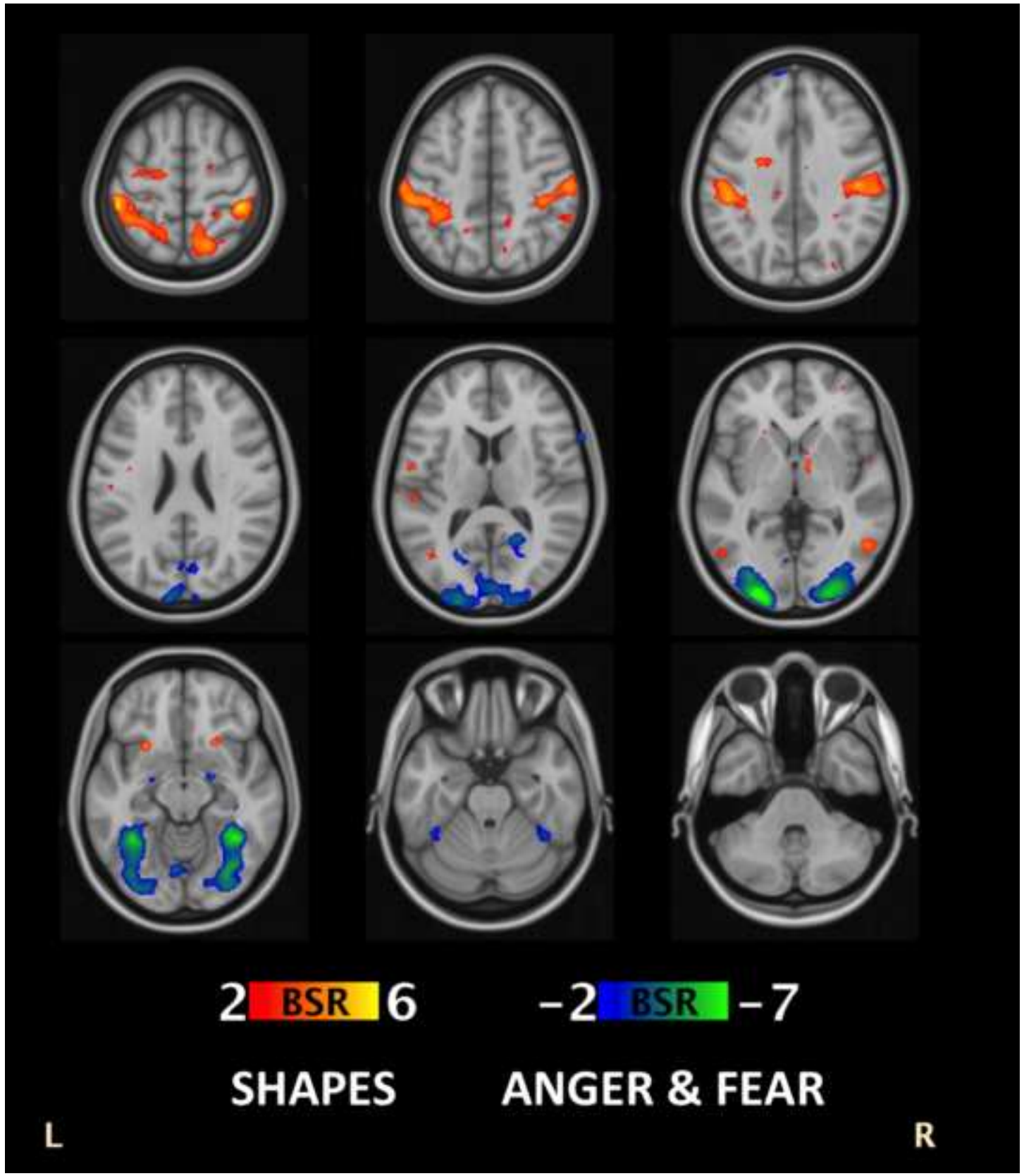


Figure 3
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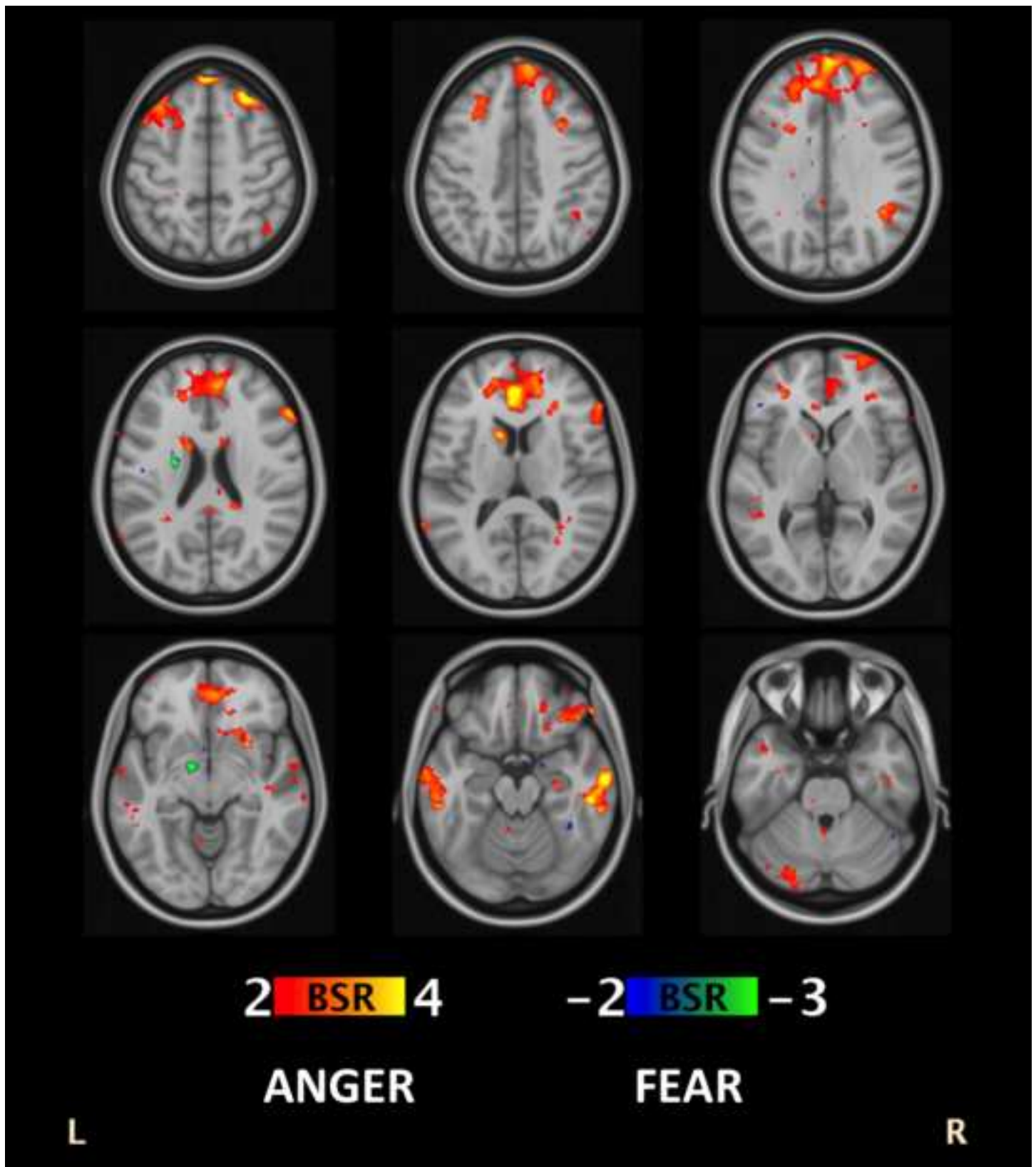


Figure 4
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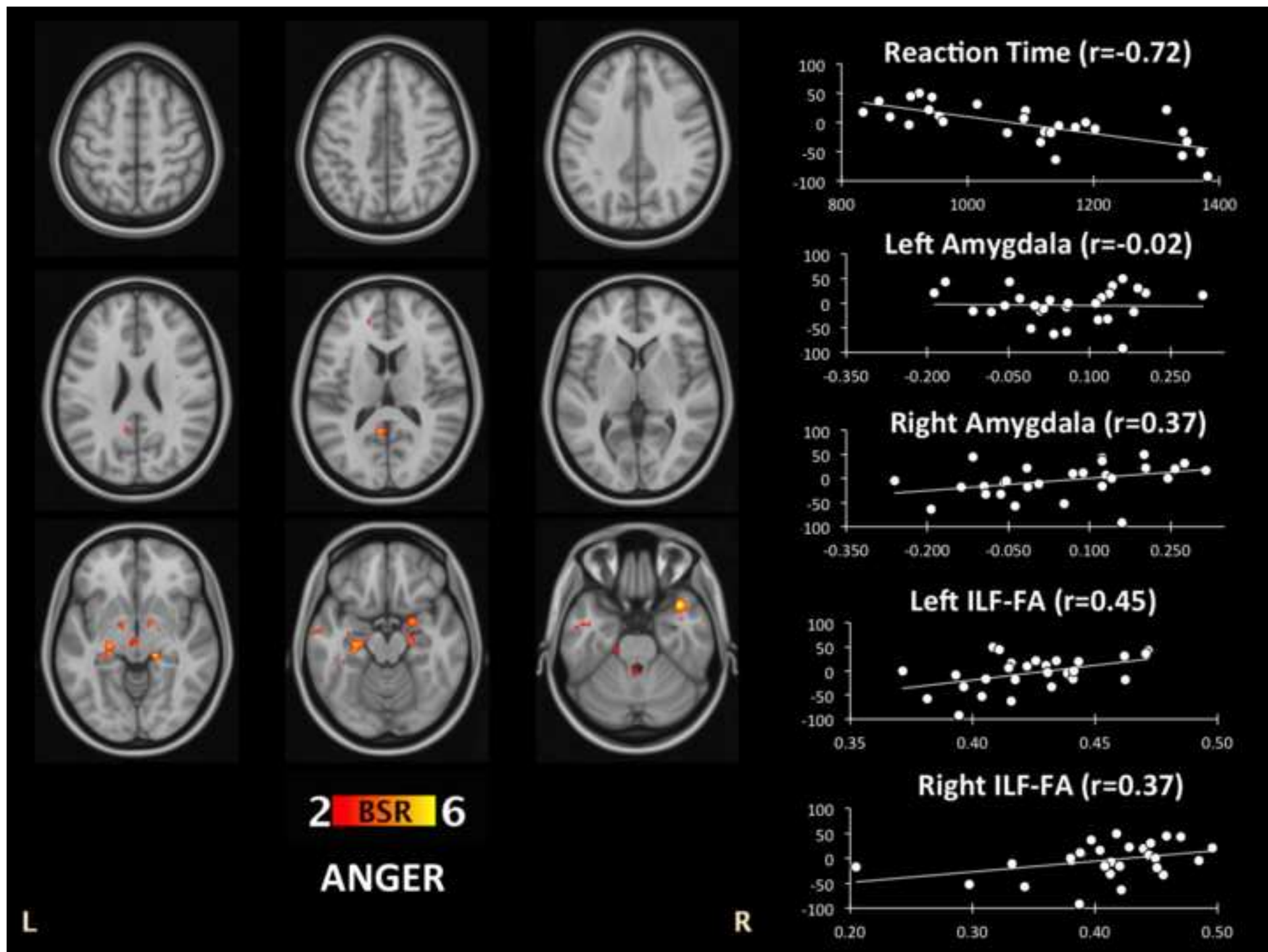


Figure 5
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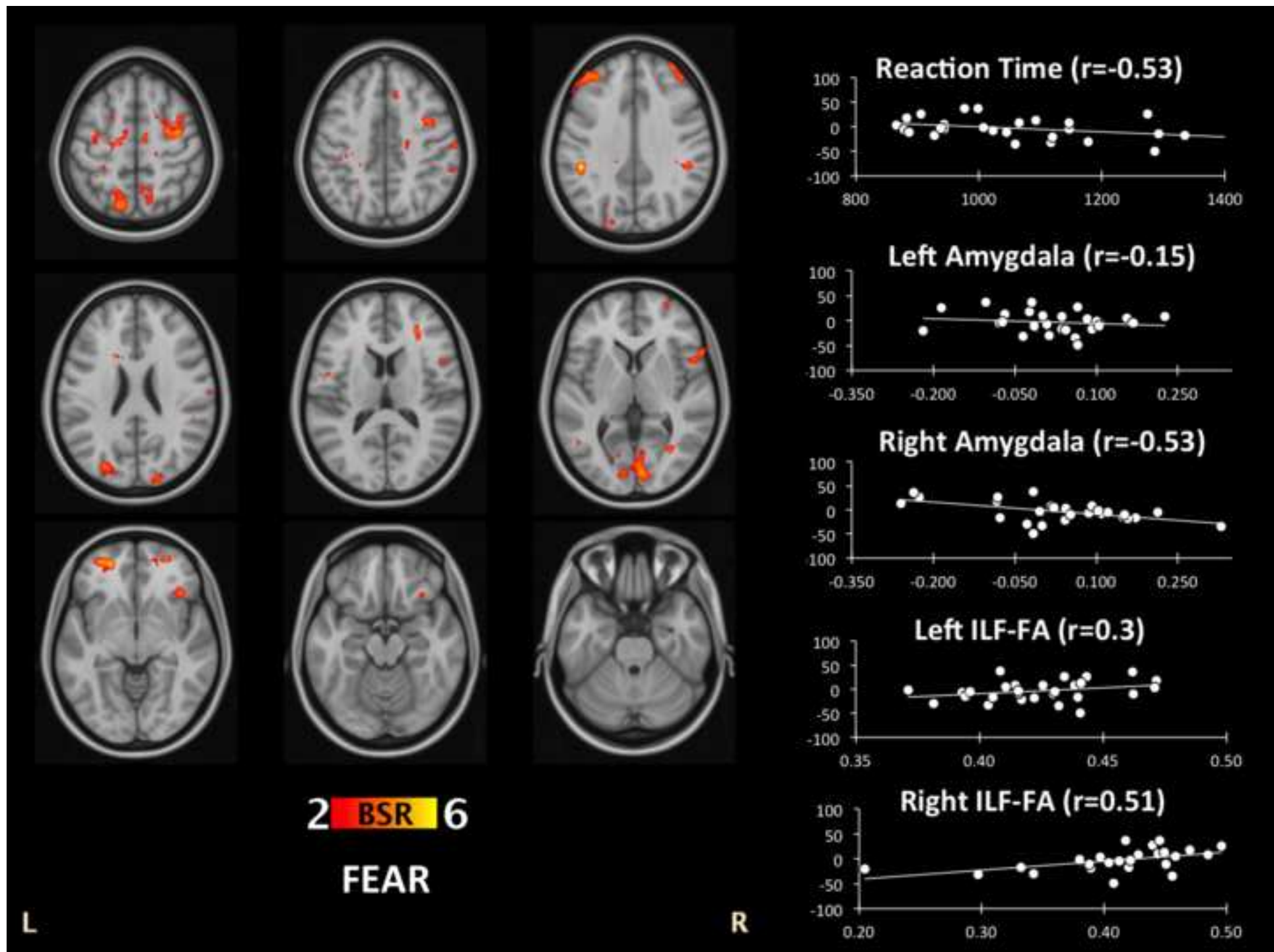


Table 1: MNI coordinates of peak voxels of whole-brain results differentiating shapes from angry and fearful face processing.

Region	Hem	MNI Coordinates			Ratio
		<i>x</i>	<i>y</i>	<i>z</i>	
Shapes > Angry & Fearful Faces					
Postcentral gyrus	L	-42	-36	54	6.1
	R	44	-36	64	7.6
Superior parietal lobule	L	-26	-46	56	6.7
Angry & Fearful Faces > Shapes					
Amygdala	L	-20	-8	-12	-4.0
	R	22	-6	-12	-4.3
Fusiform gyrus	L	-34	-50	-14	-6.8
	R	38	-46	-20	-9.4
Superior occipital cortex	L	-24	-94	0	-8.3
	R	28	-94	4	-8.1

Table 2: MNI coordinates of peak voxels of whole-brain results differentiating angry from fearful face processing.

Region	Hem	MNI Coordinates			Ratio
		<i>x</i>	<i>y</i>	<i>z</i>	
Angry > Fearful Faces					
Middle frontal gyrus	L	-30	32	50	3.7
	R	28	34	52	5.0
Ventrolateral prefrontal cortex	R	56	26	16	4.0
Frontal orbital cortex	R	32	30	-16	3.6
Anterior cingulate cortex	L	-2	42	10	4.8
Supramarginal gyrus	R	42	-48	34	3.4
Middle temporal gyrus	L	-64	-8	-18	3.4
	R	64	-14	-16	5.3
Caudate	L	-10	12	10	4.3
Fearful > Angry Faces					
Amygdala	R	18	-4	-18	-2.5
Pallidum	L	-12	-4	-6	-4.0
Fusiform gyrus	R	38	-46	-18	-2.3