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Research report

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

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ARTICLE INFO

Article history:
Received 20 May 2016
Reviewed 6 June 2016
Revised 12 July 2016
Accepted 6 October 2016
Action editor Ahmad Hariri
Published online 19 October 2016

Keywords:
Emotion discrimination
Structural–functional connectivity
Individual differences

ABSTRACT

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

1. Introduction

Rapid and accurate discrimination of facial expressions of emotion is important for preparing adequate and timely responses in social interactions (Cisek & 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, Milders, de Gelder, & Sahraie, 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

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http://dx.doi.org/10.1016/j.cortex.2016.10.001

extended emotional system centered on the amygdala (Gobbini & Haxby, 2007; Haxby, Hoffman, & Gobbini, 2002; Rossion et al., 2003). 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, Taylor, Grupe, Curby, & Schultz, 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 (ILF) (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; Vuilleumier, Armony, Driver, & Dolan, 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-related social interactions. However, to date, no study has investigated whether the functional and structural connectivity between the amygdala and fusiform gyrus affects the speed of emotion discrimination in healthy adults.

The objective of this study was to investigate whether individual differences in structural integrity and functional connectivity between the core and extended emotional face-processing networks would predict the speed of conscious emotion discrimination for angry and fearful facial expressions. In particular, we were interested in the three-way relation between structural connectivity, functional connectivity, and behaviour during an emotion discrimination task that required participants to match facial expressions of fear or anger. As an indicator of structural connectivity, we assessed the white matter integrity of the ILF, which constitutes the major white matter pathway along the ventral visual processing stream, mediating the interactions between the amygdala and the fusiform gyrus during face processing (Catani, Jones, Donato, & Ffytche, 2003; Thomas et al., 2009). As an indicator of functional connectivity, we used a seed-based approach and covaried functional activity within the amygdala with task-related activity across the whole brain. As an indicator of behaviour, we measured reaction times of emotion discrimination. Based on previous studies, which show that angry and fearful faces are identified equally fast and that processing of both emotions engages the core and extended face-processing networks (De Sonneville et al., 2002; Whalen et al., 2001), we hypothesized that, as a group, participants would (i) be equally fast to match angry and fearful faces and (ii) engage the core and extended face processing networks for both facial expressions. Based on the assumption that the discrimination of different emotional expressions requires the interaction between the amygdala and fusiform gyrus (Herrington et al., 2011; Wang et al., 2016), we further hypothesized that (iii) for both angry and fearful facial expressions, individuals who discriminate emotions more rapidly would also have better white matter integrity in the ILF and increased functional connectivity within and between the core and extended face-processing networks. More specifically, we hypothesized that shorter reaction times should correlate with higher FA values as well as connectivity values in the face processing network.

2. Methods

2.1. *Participants*

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

2.2. *Experimental procedure*

Participants took part in an emotion-matching task adapted from the paradigm described in Hariri, Bookheimer, and Mazziotta (2000). During each trial, three images were presented, one in the top and two in the bottom half of the screen using Presentation software (Neurobehavioral Systems, Inc.). One of the bottom two images was identical to the top image and participants were asked to identify the image in the bottom half of the screen that matched the top image by pressing one of two buttons associated with the left and right image. Images either showed black elliptical shapes angled at 45° or 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 msec or longer than 1800 msec.

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 3 sec to either “match the faces” or to “match the shapes”. In each trial, the images were presented for 2 sec followed by a fixation cross for 1 sec.

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