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The tendency to trust is reflected in human brain structure

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ABSTRACT

Trust is an important component of human social life. Within the brain, the function within a neural network implicated in interpersonal and social-cognitive processing is associated with the way trust-based decisions are made. However, it is currently unknown how localized structure within the healthy human brain is associated with the tendency to trust other people. This study was designed to test the prediction that individual differences in the tendency to trust are associated with regional gray matter volume within the ventromedial prefrontal cortex (vmPFC), amygdala and anterior insula. Behavioral and neuroimaging data were collected from a sample of 82 healthy participants. Individual differences in the tendency to trust were measured in two ways (self-report and behaviorally: trustworthiness evaluation of faces task). Voxel based morphometry analyses of high-resolution structural images (VBM8-DARTEL) were conducted to test for the association between the tendency to trust and regional gray matter volume. The results provide converging evidence that individuals characterized as trusting others more exhibit increased gray matter volume within the bilateral vmPFC and bilateral anterior insula. Greater right amygdala volume is associated with the tendency to rate faces as more trustworthy and distrustworthy (U-shaped function). A whole brain analysis also shows that the tendency to trust is reflected in the structure of dorsomedial prefrontal cortex. These findings advance neural models that associate the structure and function of the human brain with social decision-making and the tendency trust other people.

Introduction

Trust is a valuable component of human social life. The ability to trust others strengthens social relationships and improves the efficiency of dynamic social groups. Recently, considerable progress in social-cognitive neuroscience research demonstrates that the tendency to trust is subserved by the function of specific brain regions (Adolphs, 2002; Dimoka, 2011; Krueger et al., 2007; Rilling and Sanfey, 2011). However, it is currently unknown if the tendency to trust is associated with variation in the structure of the healthy human brain. This study was designed to test the prediction that individual differences in the tendency to trust are associated with the gray matter volume in brain regions subserving interpersonal social-cognitive function.

The network of brain regions that subserve individual differences in the tendency to trust may include loci engaged during psychological tasks designed to measure trust explicitly. Trust tasks used in neuroimaging research often involve economic scenarios (such as the “trust game”) (Berg et al., 1995; Delgado et al., 2005; van den Bos et al., 2009) or the evaluation of trustworthiness of social stimuli, such as facial expressions (Todorov, 2008; Todorov et al., 2008). Across different types of trust tasks, there exists a consistent pattern of results; trust is associated with increased neural activity within brain regions involved in social evaluation and interpersonal function (Riedl and Javor, 2012; Rilling and Sanfey, 2011) that includes the ventromedial prefrontal cortex (vmPFC), amygdala and anterior insula.

The vmPFC is involved in coding value and social decision making (Rushworth et al., 2011). vmPFC activity is often observed during personal and interpersonal decision making (Cloutier and Gyurovski, 2014; Kim and Johnson, 2014), as well as emotion regulation (Silvers et al., 2014). During trust tasks, vmPFC activity is associated with reciprocity and cooperation (Cooper et al., 2010; Rilling et al., 2002; Sakaiya et al., 2013) and dynamic changes in trustworthiness of facial expressions (Killgore et al., 2013). Damage to the vmPFC is associated with abnormal social decision making (Moretti et al., 2009) and with reduced trust-based decisions during the trust game (Krajbich et al., 2009; Moretto et al., 2013). These studies support the hypothesis that vmPFC structure is a neural construct associated with individual differences in the tendency to trust.

The amygdala functions to code the emotional salience of information (Aggleton, 2000). Across a wide range of tasks, amygdala activity increases during social and emotional evaluation (Costafreda et al., 2008). Functional neuroimaging research on trust shows that the amygdala is engaged during trustworthiness evaluation of faces (Engell et al., 2007; Winston et al., 2002), and that amygdala activity correlates with the subjective evaluation of trustworthiness of social stimuli (Rule et al., 2013). Rule and colleagues (2013) recently reported that

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amygdala activity increases when making judgments related to trustworthiness and distrustworthiness. Furthermore, individuals with amygdala damage display abnormal trustworthiness evaluations of faces (Adolphs et al., 1998) and altered trust based decision making (Koscik and Tranel, 2011). Together, these findings indicate that amygdala structure may be a neural construct associated with individual differences in the tendency to trust and distrust.

The anterior insula is involved in emotional awareness and the subjective experience of emotions (Gu et al., 2013). In terms of trust, anterior insula activity is associated with trustworthiness decisions of faces (Kragel et al., 2014; Winston et al., 2002) and with trust based decisions during economic scenarios (Aimone et al., 2014; van den Bos et al., 2009). Additionally, empirical evidence indicates that the anterior insula codes both trust (Killgore et al., 2013) and distrust (Winston et al., 2002) evaluations of faces. Together, these findings support the hypothesis that anterior insula structure may correspond to individual differences in the tendency to trust.

In this study, we measured individual differences in the tendency to trust in two ways (self-report and behaviorally) and collected high-resolution structural brain imaging data from of healthy population ($n = 82$). We used a self-report measure of trust, consisting of the A1: Trust facet of the personality trait agreeableness within the NEO-PI-3. Higher scores on the Trust facet reflect a disposition to believe that other people are honest and well intentioned (Costa et al., 1991). For the behavioral measure of trust, we used a trustworthiness evaluation of faces task (Rule et al., 2013; Todorov, 2008). We used VBM8-DARTEL to quantify gray matter volume using a whole brain approach and within *a priori* regions of interest (vmPFC, amygdala and anterior insula). Based on existing functional neuroimaging evidence, we predicted that individual differences in the tendency to trust (self-report and behaviorally) would be associated with gray matter volume within the vmPFC, amygdala and anterior insula.

Methods

Participants

We recruited 82, fluent English-speaking (49 females, 33 males; mean age = 20.74 years, standard deviation = 3.02 years, 80 right-handed) adults from the University of Georgia and surrounding community to participate in a study on brain function and social behavior. All participants were screened for neurological conditions and MRI counter indications. All participants provided written informed consent as detailed in the Declaration of Helsinki, and the University of Georgia Institutional Review Board approved all procedures within this study.

Tendency to trust: Self-report

Each participant completed the NEO Personality Inventory-3 (NEO PI-3). The NEO PI-3 covers each of the Big 5 personality traits (neuroticism, extraversion, openness, agreeableness, and conscientiousness) and includes the A1: Trust facet for agreeableness. The Trust facet is designed to characterize the tendency to attribute benevolent intent to others and the disposition to believe that others are honest and well intentioned (Costa et al., 1991). An example of an item from the Trust facet is, “My first reaction is to trust people.” Empirical investigations show that the Trust facet has high internal consistency (Costa and McCrae, 1995; Costa et al., 1991) and is a valid metric to quantify the biological basis of the tendency to trust (Cardoso et al., 2013). Prior psychometric analyses of the A1: Trust facet of agreeableness shows high convergent and discriminant validity (Costa et al., 1991). Data were scored to represent *T*-values, with the population mean defined as $T = 50$ and one standard deviation of $T = 10$. The sample scores for Trust ($M = 46.85$, SD = 11.99) were within the range of the normal non-clinical population. Reliability analysis for all items within the Trust facet showed high internal consistency (Chronbach's $\alpha = .81$).

Tendency to trust: Behavior

Each participant completed a behavioral task designed to measure trustworthiness evaluation of faces (Rule et al., 2013; Todorov, 2008). Each participant was presented with thirty-six photographs of people displaying neutral facial expressions, selected from a standardized database of face stimuli (Minear and Park, 2004). Of the thirty-six photographs, half (18) were female and half were male. Each participant was instructed to evaluate each face, based on how “trustworthy the person in the photograph appeared to be,” on a seven point Likert scale, with 1 being “distrust” and 7 being “trust.” Mean trustworthiness evaluations were calculated for each participant. Reliability analysis for all of the faces rated on trustworthiness showed high internal consistency (Chronbach's $\alpha = .94$). Mean trustworthiness evaluation of faces values did not differ according to sex or age of participants ($p > .10$).

MRI data acquisition

High-resolution whole-brain imaging data using a T1-weighted spoiled grass gradient recalled sequence were acquired on a GE-Signa 3.0 T scanner (General Electric, Milwaukee, WI) at the University of Georgia Bio-imaging Research Center (UGA BIRC: http://birc.uga.edu/). The following parameters were used: repetition time, 24 ms; echo time, 4.5 ms; flip angle, 20°; matrix size, 256 × 256; field of view, 25.6 cm; slice thickness, 1.0 mm; 164 contiguous slices.

MRI data preprocessing

Images were initially visually inspected for artifacts or structural abnormalities. VBM analyses were performed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) as implemented through the VBM8 toolbox. First, the origin of each participant's structural image was manually set to the anterior commissure. Next, each image was segmented into gray matter, white matter, and cerebrospinal fluid, and then transformed to MNI stereotactic space using affine and non-linear spatial normalization. The segmented images were then iteratively registered by the Diffeomorphic Anatomical Registration Through Exponentiated Lie algebra toolbox (Ashburner and Friston, 2000). This process created a template for the group of individuals. The resulting template image was transformed to MNI stereotactic space using affine and non-linear spatial normalization with intensity modulation by the Jacobian determinant of the deformation flow field computed for each image. The resulting images were transformed to MNI space and smoothed with an isotropic Gaussian kernel of 10 mm full width at half maximum.

Voxel based morphometry (VBM) analysis

We used a multiple regression analysis, within SPM8 software, to investigate the association between each trust metric (self-report and behavioral) and gray matter volume. For all analyses, age, sex and total cranial volume were entered as covariates. First we examined the association between self-report (Trust facet) scores and regional gray volume. Next, we examined the association between mean trustworthiness evaluation of faces values (behavioral measure) and regional gray matter volume. Lastly, we investigated the association between both trust measures and regional gray matter volume by performing a whole brain analysis with both trust measures entered as independent variables. To protect against false positive (Type 1) errors, we used a combined non-parametric and parametric statistical approach. First, we used a non-parametric approach to create an inclusive mask for areas that survived a whole brain (FDR-corrected, $p < .05$) analysis, using threshold free cluster enhancement (TFCE) (Smith and Nichols,