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Relationship between trust in neighbors and regional brain volumes in a population-based study

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ABSTRACT

Trust is a fundamental part of human interpersonal relationships, and among other complex factors it is shown to be linked with demographic characteristics and specific regions of the brain. The authors utilized a large, community-based database gathered from the Dallas Heart Study to determine specific brain regions associated with an individual's trust in neighbors. A trust questionnaire was taken and regional brain volumes were determined from structural magnetic resonance imaging. Two analyses using logistic regressions in a training set and validation set were performed to investigate the association between measures of trust and bilateral brain region volumes and thickness. A total of 1527 participants were included in the final analysis. Right caudal anterior cingulate cortex thickness and left caudate volume were inversely correlated with neighbor trust, while left amygdala volume was positively correlated with neighbor trust. Greater age and higher level of education were positively correlated with neighbor trust. African Americans showed less neighbor trust than Caucasians and Hispanics. Anterior cingulate cortex, caudate, and amygdala are all integral parts of the salience network; thus, results of this study suggest that the salience network, the brain network responsible for functions such as communication and social behavior, may play a role in the formation of interpersonal trust.

1. Introduction

A defining characteristic of humans is the ability to trust and cooperate with genetically unrelated strangers (de Quervain et al., 2004). Trust is an integral part of human interpersonal relationships and social structure (Krueger et al., 2007) when creating communities and systems. Interpersonal trust can be characterized as a combination of cognition (thinking) and affect (feeling or emotions), as it relates to balancing risk versus reward based on expectations of another person's behavior (Borum, 2010). The idea of knowing whom to trust is a vital but complex process of balancing cooperation with the potential for betrayal (Smith-Collins et al., 2013). Making the decision to trust depends also on the actions of others (Rilling et al., 2002). The ability to link human behavior to neural correlates contributes to our understanding of the neuroscience of brain mapping and improves our understanding of how these psychological processes affect the social sciences (Dimoka, 2011).

According to a 2015 Pew Research Center study, 52% of Americans reported they trusted all or most of their neighbors (PEW Research Center, 2016, April 13). This poll also found that higher levels of education, older age, and Caucasian race were associated with greater neighbor trust. Besides demographic characteristics, investigators have also used a variety of laboratory paradigms and imaging modalities to examine the neurobiologic underpinnings of trust. One study found that the prefrontal cortex (responsible for social decision making and cooperation/reciprocity), amygdala (center for processing emotions associated with decision making), and anterior insula (responsible for emotional awareness) played a role in the social-cognitive processing responsible for the development of trust (Haas et al., 2015). This finding has been confirmed by other studies which have found that individuals with a larger grey matter volume in the anterior insula and prefrontal cortex trust more easily (Adolphs, 2002). The amygdala in particular appears important to understanding the role of trust. Several studies have identified the amygdala as crucial to the development and expression of non-pathological interpersonal trust (Adolphs et al., 1998; Koscik and Tranel, 2011). An fMRI study also implicated the dorsal striatum (caudate nucleus and putamen), anterior paracingulate cortex, and orbitofrontal cortex in the neural correlates of trust (Dimoka, 2011). Furthermore, studies using functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) have also

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identified the striatum and anterior cingulate cortex (ACC) as regions of interest in the formation of interpersonal trust (Borum, 2010). The ACC is generally divided into two major sections, the caudal/dorsal ACC and the rostral/ventral ACC, and there are data suggesting that these areas may serve separate roles in emotional processing (Stevens et al., 2011). These data suggest that the ACC may play a crucial role in the in the evaluation and appraisal of developing trust and evaluating threats (Etkin et al., 2011; Heatherton, 2011).

While both demographic characteristics and brain regions appear to be important in determining level of trust, associations between specific brain regions and trust of neighbors have not, to our knowledge, been investigated in a large diverse multi-ethnic population. The ability to develop trust among neighbors is a fundamental skill in being able to develop a sense of community, foster social cohesion, create a safe environment, achieve common goals, and lead to cooperation for survival (Garoon et al., 2016). Furthermore, studies have also shown that strong trust in neighbors is associated with improved health (Bjornstrom, 2011). Given the importance of interpersonal trust among neighbors for the development of productive social systems, further exploration into the brain regions associated with trust as it relates to neighbors in a large multi-ethnic population will contribute to our understanding of human behaviors.

The aim of this study was to examine the relationship between volumes of brain regions of interest (ROI) associated with trust in prior studies and self-reported trust of neighbors. The authors utilized data from the Dallas Heart Study (DHS), a large and multiethnic epidemiologic sample of Dallas County residents. The objective was to determine which ROI are associated with neighbor trust and to use the large sample size ($n = 1527$) to explore demographic characteristics that might influence this relationship.

2. Methods

2.1. Study sample

The DHS is a large, multiracial, multiethnic, and socially diverse community-based study that included an epidemiologic sample of adults living in Dallas County, Texas. The first phase of the DHS (DHS-1) was conducted from 2000 to 2002 and was designed to examine cardiovascular disease risk factors and collect data for future research. The study intentionally oversampled African American participants to constitute close to 50% of the cohort population, in order to have sufficient power to examine cardiovascular disease risk factors in this subpopulation. Despite being a cardiovascular study, the participant sample was not a clinical population selected for the presence or absence of diseases. The data obtained from DHS-1 included a questionnaire in which participants reported their level of trust in their neighbors. The design of DHS-1 and the details on its design and recruitment methods have been described in detail previously (Victor et al., 2004).

The second phase of the Dallas Heart Study (DHS-2) was conducted from 2007 to 2009. In DHS-2, participants from the initial DHS-1 were asked to participate in a follow-up study approximately 7 years later. As part of DHS-2, some participants underwent brain MR imaging at The University of Texas Southwestern Medical Center. DHS-2 participants were either male or female, 18–80 years old, residents of Dallas County, and participants of DHS-1 during which the questionnaire was completed.

Demographic characteristics included in this study consisted of self-reported race/ethnicity (African American, Caucasian, Hispanic, or other), level of education (quit high school, high school graduate, or post high school), age, and gender.

Participants included in the present study were selected from a cohort population of people who participated in both DHS-1 and DHS-2 ($n = 2485$ participants). The Institutional Review Board at The University of Texas Southwestern Medical Center approved the study, and all participants provided written informed consent.

2.2. Measures of interpersonal trust

A questionnaire administered to all participants in DHS-1 asked participants to answer, "People in this neighborhood can be trusted" with "Strongly agree", "Somewhat agree", "Somewhat disagree", and "Strongly disagree" being listed as possible answer choices. A new neighbor trust variable was computed by dichotomizing the original trust variable. The new neighbor trust variable was created by recording "strongly agree" and "somewhat agree" responses into one "agree" value, as well as collapsing "strongly disagree" and "somewhat disagree" responses into a single "disagree" value. The responses were dichotomized in this fashion because only 10.3% of responders answered, "strongly disagree" along with 18.5% answering "somewhat disagree", 50.4% answering "somewhat agree", and 20.8% answering "strongly agree". The neighbor trust question used in the DHS-1 study was derived from a neighborhood questionnaire developed for the 1994 Project on Human Development in Chicago (Powell-Wiley et al., 2013).

2.3. MR imaging protocol and imaging analysis

Brain MR images were collected using a 3-T MR imaging system (Achieve, Phillips Medical Systems) at The University of Texas Southwestern Medical Center, using protocols and techniques previously discussed elsewhere in detail (Gupta et al., 2015). Quantification and separation of distinct brain MR regions was performed using FreeSurfer image analysis software, version 4.4 (Boston, Massachusetts: Martinos Center for Biomedical Imaging). The details of the FreeSurfer tool kit used for automated segmentation of brain regions have been described previously (Desikan et al., 2006). Images were reviewed during quality control by a trained observer and reviewed for exclusion by two neuroradiologists; abnormalities flagged during image exclusion included lesions occupying a large space, cortical strokes, brain tissue loss, metal artifacts, and image processing errors (Gupta et al., 2015). Exclusion criteria for MR imaging were applied for participant safety. These included individuals with a history of brain surgery, metal fragments, pacemakers, implantable cardio-defibrillators, cochlear implants, spinal cord stimulators, internal electrical devices, and participants who were pregnant.

2.4. Statistical analysis

Two analyses were done to evaluate the predictive ability of brain regions, total brain volume (TBV), age, gender, ethnicity (African Americans, Caucasians, Hispanics, and Others), and level of education (quit high school, graduated high school, and post high school) on neighbor trust. The bilateral brain regions of interest (ROIs) included caudal and rostral anterior cingulate cortex volume and cortical thickness, posterior cingulate cortex volume, frontal pole volume, medial orbitofrontal volume, lateral orbitofrontal volume, rostral middle frontal volume and thickness, superior frontal volume and cortical thickness, inferior temporal volume and thickness, cuneus volume, amygdala volume, insula volume, thalamus volume, caudate volume, putamen volume, and accumbens volume. These brain regions were selected because they had been implicated in prior research studies on trust (Adolphs et al., 1998; Borum, 2010; Dimoka, 2011; Etkin et al., 2011; Haas et al., 2015; Menon, 2015). The objective was to determine which of these brain regions that have been implicated in some aspects of trust might be related to trust of neighbors. Furthermore, given biases and problems involved with using ICV (intracranial volume) in Freesurfer and prior studies suggesting TBV providing a better representation, TBV was used in the analysis (Klasson et al., 2018). With regard to the demographics, due to the overrepresentation of African Americans along with wanting to capture the psychosocial differences among the ethnic groups, the ethnicity variable was dummy coded into four groups (i.e. African American, Caucasian, Hispanic, and Other) resulting in three dummy variables that were entered into the analysis as predictors. Given that the sample primarily comprised of African American participants, the reference group is African Americans. Similarly, the education variable was also dummy coded into three groups (ie. quit high school, graduated high school, and post high school) resulting in two dummy variables as predictors with the largest group being post-high school education as the reference group. Prior to conducting the analyses, the sample was randomly split (50/50) such that for both analyses $n = 763$ and $n = 764$. The resulting sub-samples are referred to as the training set and validity set.

In the first analysis, a forward stepwise binary logistic regression was conducted using SPSS version 25 software (Armonk, New York: IBM Corp) in order to create the training set. This variable selection procedure is exploratory in nature and is advantageous when there are a large number of potential explanatory variables (Zhang, 2016). Due to there being no a priori hypotheses about which variables are most salient in predicting neighbor trust, all 47 potential predictor variables were considered in the stepwise regression. The selection process is automated by SPSS during which the best predictors are selected in an iterative fashion based on adjusted R^2 values and p-values (Zhang, 2016). For example, in iteration 1, SPSS enters the strongest predictor based on whether its b-coefficient is statistically significant at alpha = 0.05. In subsequent iterations, the next strongest predictor is added while simultaneously removing previous predictors if they become statistically non-significant with the inclusion of the new predictor variable. The process continues until there are no excluded predictors that could statistically significantly contribute to the model and all variables have been analyzed.

Given that literature suggests that stepwise regression poses a few concerns (Flom and Cassell, 2007; Harrell, 2001) including biased parameter estimates and R^2 values, unknown distributions, and artificially small standard errors, a second analysis was then performed. In the second analysis, the results found in the stepwise regression analysis were confirmed using the validity set in a binary logistic regression.

For all analyses, age, gender, race/ethnicity, education, and total brain volume were used as independent covariates. Interaction terms between the specific ROI and covariates of gender, age, ethnicity, and education were conducted to evaluate a potential interaction effect between brain ROI and covariates. Chi-square analyses were run for categorical variables (e.g., gender, ethnicity), and independent sample t-tests were performed to assess for statistically significant differences in the continuous variables (education, age, total brain volume, and the independent measures of neighbor trust) between the excluded and included samples. Statistical significance was defined by a p-value of less than 0.05.

3. Results

Of the initial cohort of 2485 individuals who participated in both DHS-1 and DHS-2, 958 participants were excluded from the neighbor trust analysis due to missing data from either the trust questionnaire in DHS-1 or MR imaging in DHS-2, with a majority ($n = 854$) excluded due to the latter. A total of 1527 participants were included in the final analysis of the neighbor trust metric. The final sample determination for the regression analysis is described in Fig. 1.

Participants excluded due to missing data ($n = 958$) were found to

Table 1
Descriptive statistics for included and excluded participants.

Variable	Included $n = 1527$		Excluded $n = 958$	
	n	%	n	%
Sex				
Male	667	43.7	385	40.2
Female	860	56.3	573	59.8
Race/Ethnicity				
African American	706	46.2	579	60.4*
Caucasian	538	35.2	201	21*
Hispanic	257	16.8	153	16
Other	26	1.7	25	2.6*
Education				
Quit high school	192	12.6	161	18.1*
High school graduate	348	22.8	267	30.0*
Post high school	987	64.6	463	52.0*
People in neighborhood can be trusted				
Somewhat or Strongly Disagree	414	27.1	267	31.9
Somewhat or Strongly Agree	1113	72.9	569	68.1
	Mean	SD	Mean	SD
Age (years)	50.01	10.16	51.52	10.52*
Total Brain volume (ml)	1131.37	243.94	1113.34	237.16
Temporal Gap of DHS1 & DHS2 (years)	6.805	0.7338	7.012	0.7285

Note. $^*p < 0.05$ (Bonferroni adjusted). T-tests were used to compare included and excluded participants on continuous outcomes; chi-square analyses were used to compare included and excluded participants on categorical outcomes. SD: Standard deviation.

have statistically significant differences in ethnicity, education, and age compared to the samples included in the analysis ($n = 1527$). However, there were no significant differences in gender, total brain volume mean, temporal gap between DHS 1 and DHS 2, or in responses to the neighbor trust question. The demographics of the included and excluded subjects are described in Table 1. A cross-tabulation between the four different ethnic groups and demographic characteristics including gender, education, and age of the included participants ($n = 1527$) are described in Table 2. Furthermore, a comprehensive list of all the brain ROIs that were included in the analysis is listed in Table 3.

To evaluate for potentially moderating effects between the specific ROIs, covariates, and the possible need for sub-group analyses, interaction terms were created. Interaction terms of all the ROIs by gender, age, ethnicity, and education were conducted and no significant interaction was found.

Table 4 shows the results of the first analysis using a forward stepwise binary logistic regression in the training set ($n = 763$). Due to the variable selection process being exploratory in nature and no a priori hypotheses about which variables are most salient in predicting neighbor trust, all the brain regions of interest (ROIs) and demographic co-variants (ie. age, gender, ethnicity, education) were included in this first analysis. The selection process was automated by SPSS during which the best predictors/variables are selected in an iterative fashion based on adjusted R^2 values and p-values (Zhang, 2016). With each iteration, the strongest predictors were selected based on whether or not its b-coefficient is statistically significant at alpha = 0.05 while simultaneously removing previous predictors if they become non-significant as new predictors are added in subsequent iterations. In the present analysis, there were nine iterations during which each co-

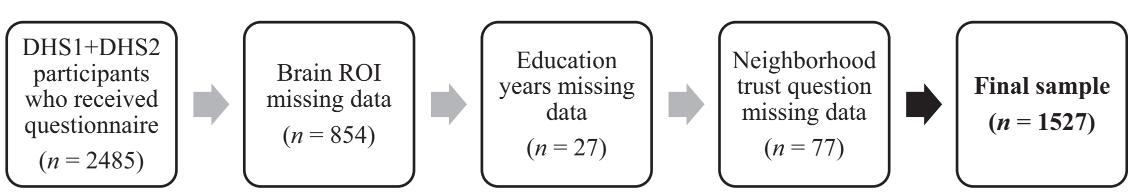

Fig. 1. Final sample determination for regression analysis. DHS1: Dallas Heart Study, phase 1; DHS2: Dallas Heart Study, phase 2; ROI: Regions of interest.

Table 2
Cross-tabulation of ethnicity by demographic characteristics.

Variable	African American n = 706		Caucasian n = 538		Hispanic n = 257		Other n = 26	
	n	%	n	%	n	%	n	%
Sex								
Male	313	44.3	256	47.6	108	42	12	46.2
Female	393	55.7	282	52.4	149	58	14	53.8
Education								
Quit High School	82	11.6	22	4.1	70	27.2	0	0
High School Graduate	202	28.6	114	21.2	48	18.7	2	7.7
Post High School	422	59.8	402	74.7	139	54.1	24	92.3
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Age (years)	50.82	10.43	51.03	10.2	49.87	10.12	51	10.4

Note. Cross-tabulation refers to only participants included in the study (n = 1527).

Table 3
Regions of Interest (ROIs) that were included in the analyses.

Left and Right Rostral ACC Volume
Left and Right Caudal ACC Volume
Left and Right Rostral ACC Thickness
Left and Right Caudal ACC Thickness
Left and Right Posterior Cingulate Volume
Left and Right Frontal Pole Volume
Left and Right Medial Orbitofrontal Volume
Left and Right Lateral Orbitofrontal Volume
Left and Right Rostral Middle Frontal Volume
Left and Right Rostral Middle Frontal Thickness
Left and Right Superior Frontal Volume
Left and Right Superior Frontal Thickness
Left and Right Inferior Temporal Volume
Left and Right Inferior Temporal Thickness
Left and Right Cuneus Volume
Left and Right Amygdala
Left and Right Insula Volume
Left and Right Thalamus Proper
Left and Right Caudate
Left and Right Putamen
Left and Right Accumbens Area

Table 4
Results from stepwise logistic regression (Training Set).

	β	p-value	Odds ratio	95% confidence interval
Age	0.062	< 0.001	1.064	1.043, 1.086
Education[a]				
High school grad	−0.547	.007	0.579	0.388, 0.863
Quit high school	−1.132	< 0.001	0.322	0.188, 0.552
Ethnicity[b]				
Caucasian	0.614	.003	1.847	1.232, 2.768
Hispanic	0.674	.011	1.961	1.165, 3.302
Left amygdala volume	1.402	.006	4.065	1.482, 11.150
Left caudate volume	−0.373	.044	1.453	1.011, 2.088
Right caudal ACC thickness	−1.232	< 0.001	0.292	0.151, 0.563

Note. $\chi^2(9) = 96.111$, $p < 0.001$, Nagelkerke $R^2 = 0.166$. Logistic regression used only the training set (random 50% subsample). Confidence interval is for odds ratio.
[a] Education reference group: Post High School.
[b] Ethnicity reference group: African Americans.

variant and brain region was analyzed against the dichotomized neighbor trust question of "agree" or "disagree" with positive beta (B) demonstrating a positive correlation and negative beta (B) being associated with a negative correlation. In the final iteration, age, education, ethnicity, left amygdala volume, left caudate volume, and right caudal ACC thickness emerged as statistically significant predictors of neighbor trust. The results are presented in Table 4.

In order to confirm our results, a second analysis using a binary logistic regression in the validity set using all the predictors found in the first analysis was conducted. All the predictors remained statistically significant at the $p = 0.05$ level and are presented in Table 5. The results from the second analysis in Table 5 were interpreted. The primary finding was that greater right caudal ACC thickness and greater left caudate volume were shown to have a relationship with decreased neighbor trust due to having a negative beta (B), while greater left amygdala volume was correlated with increased neighbor trust due to having a positive beta (B). Among covariates including age, ethnicity, gender, and education, gender and the fourth ethnicity group of other were found to be non-significant as evidenced by not being present in the final iteration. Greater age was found to be associated with increased neighbor trust due to having a positive beta (B). With regard to education, the negative betas (B) suggest that individuals with lower levels of education (ie. quit high school or high school grad) are associated with having decreased levels of trust in their neighbors when compared to the reference group of individuals with post high school degrees. Therefore, suggesting that individuals with higher levels of education are more likely to trust their neighbors. Similarly with regard to ethnicity, the positive betas (B) suggest Caucasians and Hispanics are most likely to trust their neighbors when compared to the reference group of African Americans.

Table 5
Results from Logistic Regression (Validity Set).

	β	p-value	Odds ratio	95% confidence interval
Age	0.047	< 0.001	1.048	1.029, 1.066
Education[a]				
High school grad	−0.558	.006	0.573	0.386, 0.850
Quit high school	−1.163	< 0.001	0.313	0.183, 0.534
Ethnicity[b]				
Caucasian	0.654	.001	1.923	1.296, 2.853
Hispanic	0.689	.009	1.992	1.190, 3.333
Left amygdala volume	1.060	.019	2.887	1.192, 6.989
Left caudate volume	−0.299	.004	0.741	0.522, 1.053
Right caudal ACC thickness	−0.809	.007	0.445	0.247, 0.803

Note. $\chi^2(9) = 87.97$, $p < 0.001$, Nagelkerke $R^2 = 0.152$. Logistic regression used only the validity set (random 50% subsample). Confidence interval is for odds ratio.
[a] Education reference group: Post High School.
[b] Ethnicity reference group: African Americans.

4. Discussion

In this study, we demonstrated an association between population demographics, ROI brain volumes/thickness, and neighbor trust. While not the focus of our study, we found individuals with a higher level of education, older age, and non-African American race (ie. Caucasian and Hispanic) were more likely to trust their neighbors. These findings were similar to the results of the 2015 Pew Research Center study (PEW Research Center, 2016, April 13). Furthermore, decreased self-reported neighbor trust was associated with greater right caudal ACC thickness and greater left caudate volume, and increased self-reported neighbor trust was associated with greater left amygdala volume. Prior studies have shown increased volume in the amygdala being associated with judging the trustworthiness of faces (Haas et al., 2015), but no previous study analyzed ACC thickness or caudate volume in the context of interpersonal trust. Given that the anterior cingulate cortex, caudate, and amygdala are integral parts of the salience network, these findings suggest that the salience network may play a role in the formation of interpersonal trust.

The brain regions associated with neighbor trust are part of the salience network. The salience network is an intrinsically vast interconnected brain network that is responsible for complex functions including communication and social behavior by interpreting sensory, emotional, and cognitive information (Menon, 2015). It is mainly composed of the anterior insula, anterior cingulate cortex (ACC), amygdala, striatum, thalamus, and substantia nigra/ventral tegmental area. Abnormalities in these regions have been associated with various neurodevelopmental and psychiatric conditions including autism spectrum disorder (ASD), in which decreased salience in social stimuli may be responsible for the associated social dysfunction (Volkmar et al., 2005). Prior studies have also suggested that irregularities in the salience network result in accidental attribution to both external and internal stimuli in schizophrenia, contributing to psychotic symptoms such as delusions and hallucinations (Palaniyappan et al., 2011). When functioning properly, this paralimbic-limbic system is able to filter through multiple types of stimuli and assign importance to those stimuli that help accomplish goal-directed tasks and balance risk versus reward. Similarly, integration of various types of stimuli (cognition, emotions, and affect) and balancing risk versus reward in order to interpret or predict behavioral patterns of others are also essential characteristics of interpersonal trust (Borum, 2010).

A key component of the salience network is the ACC. The ACC is a structurally and functionally heterogeneous region of the brain with extensive connections to multiple regions resulting in roles involving motor activity (primary/premotor cortex), cognition (prefrontal cortex), emotion (amygdala), reward (orbitofrontal/striatum), and memory (hippocampus) (Margulies et al., 2007; Vogt, 2009). The ACC accomplishes these tasks partially through a unique type of neuron called Von Economo neurons (spindle neurons), found in the ACC and insula, which are responsible for adaptive and intuitive functioning in social situations along with rapid communication within the salience network (Allman et al., 2010). Furthermore, neuroimaging studies have shown that damage to the ACC results in problems in sustained attention (Devinsky et al., 1995), working memory for reinforcement learning (Kennerley et al., 2006), decreased motivation for tasks (Critchley et al., 2003), problems with language generation (Damasio and Van Hoesen, 1983), trouble with emotional responses (Etkin et al., 2011), difficulty in resolving conflicts (Botvinick et al., 2004), inability to detect errors (Holroyd and Yeung, 2012; Posner et al., 1988), and errors in information processing (Holroyd and Coles, 2002). These brain functions contribute to interpersonal trust development by integrating emotional and cognitive inputs followed by provoking a motor response and then reinforcement learning based on positive or negative outcomes. While ACC neuroimaging and activation during cognitive tasks have been previously studied, and prior studies have related ACC thickness to various psychiatric conditions including depression (Reynolds et al., 2014; Schmaal et al., 2017), PTSD (Demers et al., 2015; Dickie et al., 2013), OCD (Kuhn et al., 2013), and aggression (Ducharme et al., 2011), there have been limited studies analyzing ACC cortical thickness in the context of interpersonal trust. The present study found that increased right caudal ACC thickness is associated with decreased self-reported trust. Given that the dorsal-caudal region of the ACC is mainly responsible for expression of negative emotions (anxiety and fear) while the ventral-rostral regions play a role in producing emotional reaction (Etkin et al., 2011), our data suggest that individuals with larger caudal ACC thickness may show greater importance to negative emotions and are, therefore, less likely to trust their neighbors.

Another integral part in the salience network is the amygdala, which is responsible for processing the social and emotional salience of information (Aggleton, 2000). The amygdala acts like a "social detector" for interpersonal cues in order to make trust decisions based on anticipation of either reward or threat from others. This is exemplified by studies in which either bilateral or unilateral damage to the amygdala results in abnormal trustworthiness evaluation of faces (Adolphs et al., 1998), inappropriate responses to betrayals in trust games (Koscik and Tranel, 2011), and inappropriate social behaviors (Adolphs et al., 1998). Prior neuroimaging studies have shown increased activation in the right amygdala being associated with increased likelihood of rating a face as untrustworthy (Engell et al., 2007; Todorov and Engell, 2008; Winston et al., 2002) along with increased right amygdala volume being correlated with both a tendency to rate a face as trustworthy or untrustworthy (Haas et al., 2015). Our study instead showed a significant association between increased self-reported neighbor trust and increased left amygdala volume. Given that our study relied more on a cognitive attribute of trust rather than emotional attribute (i.e. evaluation of faces or trust games), this may explain why our study showed significant results with only the left amygdala and not the right. Furthermore, electrical stimulation studies have shown right amygdala stimulation results in only negative emotions (fear and sadness) while left stimulation induces both positive (happiness) and negative (anxiety, fear, sadness) emotions (Lanteaume et al., 2007). Studies have also shown that increased amygdala volume is correlated with larger and more complex social networks, increased emotional intelligence, and increased cooperation with others, resulting in more interpersonal trust (Bickart et al., 2011; Buchanan et al., 2009). These studies, along with our results, suggest that the left amygdala may play a larger role in the cognitive characteristic of trust due to encoding for both positive and negative emotions, with larger amygdala volumes associated with larger social networks and greater entrustment.

Additionally, the caudate, part of the striatum, also performs an essential role in the salience network with regard to cognition, executive function, goal-directed behavior, cooperation, and reward/motivation (Haber, 2016). Behavioral studies have shown that damage to the caudate leads to the disruption of the reward pathway and inability to assess the value of actions when rewards have been changed (Grahn et al., 2009). Furthermore, neuroimaging studies during trust games demonstrate increased activation in the bilateral caudate nuclei when individuals are faced with partners with a reputation for risk-taking (Wardle et al., 2013) or after successfully punishing partners who have betrayed their trust (de Quervain et al., 2004; Singer et al., 2006). These studies suggest that the caudate may play a role in signaling the presence of a "bad" partner along with anticipated approval of punishment in order to promote cooperation and interpersonal trust development. While previous studies have related caudate volume to various neuropsychiatric disorders including Alzheimer's dementia (Jiji et al., 2013), Huntington disease (Walker, 2007), ADHD (Schrimsher et al., 2002), autism spectrum disorder (Voelbel et al., 2006), schizophrenia (Takase et al., 2004), and OCD (Radua et al., 2010), there have been limited studies in the context of caudate volume and trust. The present study showed increased left caudate volume being associated with decreased self-reported trust. Given that the caudate is more active when faced with uncertain or risky decisions, these data suggest that an increased caudate volume may result in greater skepticism that leads to less trust of others.

While our study uniquely relates self-reported neighbor trust to ROI brain volumes and thickness, our findings should be considered in the context of particular limitations. Unlike other previous studies examining interpersonal trust, our study did not utilize neuroimaging in the context of a human laboratory paradigm of trust. We used a question about neighbor trust developed from the 1994 Project on Human Development in Chicago that has shown to have internal consistency and discriminant validity when used in diverse populations like in the Dallas Heart Study (Mujahid et al., 2007; Powell-Wiley et al., 2013; Sampson et al., 1997). Secondly, given the statistically significant differences in race, education, and age between the included and excluded groups in the study (Table 1), there may have been some selection bias in our final population. Furthermore, due to limitations of the data available in the DHS, not all ROIs included a cortical thickness measure. Therefore, our results and conclusions about ROI thickness can only be made with regard to those specific regions and not universally about cortical thickness. Additionally, due limitations in the original study design by DHS, which included a seven year gap between the questionnaire (DHS-1) and MR scan (DHS-2), the possibility of structural brain changes effecting the various regions along with the effects of aging (Walhovd et al., 2011) is a limitation of our study. Although the effects of aging may have led to variation in the results, the time lapse between the individuals was uniform and consistent with an average of 6.8 years. Lastly, when comparing the results of our study to other previous works, due to our study using FreeSurfer 4.4, an automated subdividing labeling system, our ROIs were different than other works that used a manual ROI subdividing system (Desikan et al., 2006). While these differences in regions may have led to some differences in results, studies have shown that automated subdividing programs consistently demonstrate highly reliable results, lower variability, greater validity, and improved reproducibility compared to manual systems (Desikan et al., 2006).

In conclusion, the present study provided new insight into the brain regions associated with trust of neighbors due to no previous study looking at this relationship. The findings suggest that regions of the salience network are associated with this type of trust and are generally consistent with functional and structural neuroimaging studies using laboratory paradigms of trust. Given the importance of trust in neighbors resulting in the creation of beneficial communities, additional future studies are needed in order to continue to better understand the driving forces both socially and neurobiologically behind these social systems.

Declarations of interests

Dr. Brown has research grants from NHLBI, NIAAA, NIA, the Stanley Medical Research Institute and Otsuka, and serves on an advisory board for Allergan. Drs. Sadhu, de Freitas Nicholson, Garcia, Lampley, Rain, Fritz, Jalalizadeh, and Van Enkevort along with Jayme Palka have no financial interests or potential conflicts of interest. mmc1.xml

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.pscychresns.2019.03.002.

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