Social Neuroscience

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/psns20

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To cite this article: William D. S. Killgore, Zachary J. Schwab, Olga Tkachenko, Christian A. Webb, Sophie R. DelDonno, Maia Kipman, Scott L. Rauch & Mareen Weber (2013): Emotional intelligence correlates with functional responses to dynamic changes in facial trustworthiness, Social Neuroscience, 8:4, 334-346

To link to this article: http://dx.doi.org/10.1080/17470919.2013.807300

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Emotional intelligence correlates with functional responses to dynamic changes in facial trustworthiness


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Emotional intelligence (EI) refers to a constellation of traits, competencies, or abilities that allow individuals to understand emotional information and successfully navigate and solve social/emotional problems. While little is known about the neurobiological substrates that underlie EI, some evidence suggests that these capacities may involve a core neurocircuitry involved in emotional decision-making that includes the ventromedial prefrontal cortex (vmPFC), anterior cingulate cortex (ACC), insula, and amygdala. In a sample of 39 healthy volunteers (22 men; 17 women), scores on the Bar-On EQ-i (a trait/mixed model of EI) and Mayer–Salovey–Caruso Emotional Intelligence Test (MSCEIT; an ability model of EI) were correlated with functional magnetic resonance imaging responses during brief presentations of moving facial expressions that changed in the level of perceived trustworthiness. Core emotion neurocircuitry was responsive to dynamic changes in facial features, regardless of whether they reflected increases or decreases in apparent trustworthiness. In response to facial movements indicating decreasing trustworthiness, MSCEIT correlated positively with functional responses of the vmPFC and rostral ACC, whereas the EQ-i was unrelated to regional activation. Systematic differences in EI ability appear to be significantly related to the responsiveness of the vmPFC and rostral ACC to facial movements suggesting potential trustworthiness.

Keywords: Emotional intelligence; Somatic Marker Hypothesis; Ventromedial prefrontal cortex; Amygdala; Insula.

Human beings vary widely in their ability to acquire new information, understand their environment, think rationally, apply their knowledge to adapt to changing conditions, solve problems, and achieve goals. Broadly speaking, these capacities comprise what is known as “intelligence” (Wechsler, 1958). While the concept of intelligence as a unitary construct has persisted for over a century, some authors have hypothesized the possible existence of multiple forms of intelligence (Gardner, 1983). In particular, the construct of emotional intelligence (EI) has garnered considerable interest both within scientific and popular writings since the mid-1990s (Bar-On, 2006; Goleman, 1995; Mayer, Salovey, Caruso, & Sitarenios, 2001). While scholars differ in the exact criteria used to define EI, most current conceptualizations generally agree that the construct involves some constellation of traits, competencies, or abilities that allow an individual to understand emotional information and successfully navigate and solve social/emotional problems (Bar-On, 2006; Mayer et al., 2001). From one perspective, EI is described as a relatively stable constellation of emotionally related competencies and traits that underlie the potential to cope adaptively with demanding situations and to use emotional knowledge to succeed in achieving goals (Bar-On, 2006). This Trait (or Mixed) model views EI as similar in many ways to personality, though more modifiable through life experience and reflection (Webb et al., 2013). In contrast, the Ability model of EI defines the construct...
in terms of measurable performance on tasks requiring the ability to solve emotional problems as well as demonstrate reasoning and knowledge about emotional processes (Webb et al., 2013). Both theoretical models continue to be actively researched and both have yielded well-normed, standardized, commercially available tests (Brackett & Mayer, 2003). At present, however, there exists very little scientific understanding of the neurocircuitry involved in EI.

One hypothesized model of the neurocircuitry underlying EI was proposed by Bar-On and colleagues (Bar-On, Tranel, Denburg, & Bechara, 2003), and suggests that the key features of EI can be parsimoniously explained by the emotional decision-making circuitry outlined by Antonio Damasio (Damasio, 1996), known as the Somatic Marker Circuitry (SMC) (Bar-On et al., 2003; Bechara & Damasio, 2005). The Somatic Marker Hypothesis (SMH) essentially provides an explanation of how the brain learns from emotional experiences and uses “somatically remembered” experiential knowledge to influence future decisions (Damasio, 1994). Simply put, the SMH suggests that our cognitive deliberations during decision-making are aided by emotional body signals, “hunches,” or “gut feelings” that were initially formed through prior experience with a stimulus or situation, and that are automatically reactivated during future encounters resembling the earlier experience. According to the SMH, three primary brain structures (in addition to many secondary ones) are involved in the development of these somatic biasing signals to influence judgment and decision-making. First, the amygdala is proposed to be responsible for triggering initial signals of emotional salience in response to a relevant stimulus that leads to enactment of the somatic states characteristic of an emotion. Second, the insula contributes to the “feeling” of emotion by neurally mapping these somatosensory and visceral sensations, which can later be “simulated” within the brain when a comparable emotion-evoking stimulus is encountered in the future. Finally, the ventromedial prefrontal cortex (vmPFC) is posited as the core integrative system that joins these somatic signals with past and present cognitive representations of stimuli and situations. Once a stimulus has been associated with a pleasant or unpleasant feeling (i.e., a somatic marker), future reactivation of these cognitive representations of the stimulus (or actual re-encounters) can evoke a similar somatic experience (i.e., a “good” or “bad” feeling), biasing subsequent judgments and decisions toward advantageous outcomes. Bar-On and colleagues suggest that the SMC is the primary neurocircuitry that underlies the capabilities and competencies that comprise EI (Bar-On et al., 2003). The anterior cingulate cortex, particularly in the rostral regions, may also serve as part of the extended medial prefrontal cortex as it plays a key role in regulating emotion and resolving emotional conflict (Etkin, Egner, & Kalisch, 2011; Etkin, Egner, Peraza, Kandel, & Hirsch, 2006).

Some data from neuroimaging studies now exist to support the role of the SMC in EI. Based on the assumption that EI capacities involve reasoning and problem solving about emotion, most studies of the neurobiological basis of this construct have focused on prefrontal cortical regions involved in problem solving and emotional regulation, as well as somatic and emotional processing regions such as the insular cortex and amygdala. Early studies using functional magnetic resonance imaging (fMRI) showed that activation of some of these hypothesized regions of the brain, particularly the medial prefrontal cortex, was negatively correlated with measures of Ability EI (Reis et al., 2007) and Trait EI (Killgore & Yurgelun-Todd, 2007). The inverse relationships between EI and brain responses to these very simple task designs, using static fearful facial expressions or rule-based card selection tasks, were interpreted as evidence of neural efficiency, suggesting that individuals possessing greater EI were able to engage in emotional processing with less neural and cognitive effort (Killgore & Yurgelun-Todd, 2007). Whereas those initial studies compared emotional/social-processing tasks to resting baseline, a subsequent study using a more complex auditory paradigm with a nonresting comparison condition found positive correlations between EI and some cortical emotional processing regions, while failing to find activation in more primitive regions such as the amygdala (Kreifelts, Ethofer, Huberle, Grodd, & Wildgruber, 2010). Recent structural neuroimaging studies have also suggested that measures of EI are related to gray matter volume within the vmPFC (Killgore et al., 2012; Koven, Roth, Garlinghouse, Flashman, & Saykin, 2011; Takeuchi et al., 2011), further supporting this region as a potentially important contributor to EI capacities.

A key aspect of social and emotional intelligence involves the ability to discriminate between individuals who are safe to approach and those who should be avoided (Winston, Strange, O’Doherty, & Dolan, 2002). The amygdala, one of the regions involved in the SMC, appears to be critical to this process. Prior work has shown that lesions to the amygdala can impair the ability to distinguish between trustworthy and untrustworthy individuals based on facial appearance (Adolphs, Tranel, & Damasio, 1998) and that such lesions often lead to inappropriate levels of social trust (Koscik & Tranel, 2011). Other work suggests that the vmPFC is also important to these types of
social judgments involving the ability to discriminate trustworthy from untrustworthy individuals (Kosic & Tranel, 2011). The vmPFC may be especially important in the process of integrating social, emotional, and cognitive information for determining trustworthiness decisions (Bzdok et al., 2012; Damasio, 1994). While the vmPFC is highly complex and involved in many aspects of social and emotional functioning, consistent evidence suggests that it is particularly activated when a person is considering the mental state or goals of another person (Frith, 2007). At present, no research has examined the relationship between EI capacities and the responsiveness of these brain regions to social trust stimuli.

The goal of the present study was to build upon the prior work evaluating the relationship between EI and SMC responses to simple static facial expressions by using a more ecologically valid task of processing dynamically changing facial attributes affecting trustworthiness judgments. In the “real world,” facial features are rarely static, and clues to the intentions of others often come from the subtle changes in facial movement that occur during interpersonal exchanges. Here, during fMRI, we presented healthy participants with brief glimpses of faces that rapidly and dynamically changed in features associated with perceived trustworthiness. In each condition, faces either morphed from appearing highly trustworthy to neutral (i.e., decreasing in trustworthiness) or from neutral (i.e., increasing in trustworthiness) or from low trustworthiness to neutral (i.e., increasing in trustworthiness). We hypothesized that higher scores on tests assessing both Trait and Ability models of EI would be associated with increased activation of the primary nodes of the SMC, particularly the vmPFC, in response to dynamically changing facial expressions indicative of decreasing trustworthiness.

**METHODS**

**Participants**

Thirty-nine right-handed healthy volunteers (22 men; 17 women) ranging in age from 18 to 45 years \((M = 29.9, SD = 8.6)\) participated in the study. All participants had completed at least 11 years of formal education \((M = 15.0, SD = 2.0)\) and were native English speakers. The sample was racially diverse, including 24 individuals self-identified as Caucasian (61.5%), 8 as African American (20.5%), 4 as Asian American (10.3%), and 3 as “other” or “multi-racial” (7.7%). Volunteers were recruited via Internet advertisements and posted flyers within the Boston metropolitan area and were paid for their participation. Based on a detailed screening interview including questions adapted from the Structured Clinical Interview for DSM-IV Disorders (SCID-I/P) (First, Spitzer, Gibbon, & Williams, 2002), potential subjects were excluded for any history of Axis I mental disorder, neurological illness, head injury with loss of consciousness >30 minutes, sleep-related disorder, current use of psychotropic medications or substances known to affect functional neuroimaging, or current chemotherapy or radiation therapy. Written informed consent was obtained from all participants. The McLean Hospital Institutional Review Board approved the procedures for this study.

**Materials and procedure**

Following completion of the informed consent process, each participant completed computerized administrations of two well-validated commercially available tests of EI. The Bar-On Emotional Quotient Inventory (EQ-i) (Bar-On, 2002) was included as an index of Trait (or Mixed) EI. The EQ-i comprises 125 self-report items that yield a Total EQ score and five composite scores (i.e., Interpersonal, Intrapersonal, Adaptability, Stress Management, and General Mood). Individuals scoring high on the Interpersonal scale describe themselves as empathic and interpersonally aware, while those scoring high on the Intrapersonal scale describe themselves as self-aware, in-tune with their own emotions, and high in self-esteem. High scorers on the Adaptability scale perceive themselves as objective problem solvers who can adapt quickly to new situations. Those high in Stress Management describe themselves as well-controlled and unflappable in difficult or stressful situations. Individuals with high scores on the General Mood scale are self-described positive thinkers who are content with life. All EQ-i scores were scaled based on the general normative group, without adjustment for sex. To measure Ability EI, participants also completed the Mayer–Salovey–Caruso Emotional Intelligence Test (MSCEIT) (Mayer, Salovey, & Caruso, 2002), which includes 141 computer-administered items to assess individual skill at identifying, understanding, and using emotions. The test presents the participants with various types of stimuli that have to be rated for emotional characteristics or potential solutions that need to be selected to effectively address a given emotionally salient situation. The MSCEIT yields a Total EI score and two area scores, Experiential EI and Strategic EI. High scorers on Experiential EI are skilled at perceiving emotions and are effective at using that information to facilitate thought and
performance. This area includes two subscales measuring abilities described as Perceiving and Facilitating emotions. The second area is Strategic EI. Those scoring high on this area have excellent capacity for understanding emotional information and are skilled at managing emotions in themselves and in others. Strategic EI comprises two subscales measuring abilities described as Understanding and Managing of emotions. MSCEIT scoring was based on the consensus scoring methods outlined in the manual (Mayer et al., 2002). Following completion of the EI tests, participants underwent structural and functional neuroimaging.

Dynamic facial trustworthiness task (DFTT)

During fMRI, participants completed a 4-minute task involving the visual perception of dynamically changing facial displays of trustworthiness. The face stimuli were selected from a freely available database (http://webscript.princeton.edu/~tlab/databases/database-6-trustworthiness-dataset/) of 100 computer-generated facial identities at three different trustworthiness levels. These faces were generated using the FaceGen 3.1 modeling program (http://facegen.com) and morphed to vary along the dimension of trustworthiness according to the methods described by Oosterhof and Todorov (2008). Briefly, that group used the computer-modeling program to generate 300 neutral faces of European origin, which were then subsequently rated by 29 judges on a 9-point scale of trustworthiness. By mathematically identifying the features in the faces that related to the dimension of trustworthiness, Oosterhof and Todorov (2008) randomly generated a new set of computer-generated faces varying systematically in these characteristics along a scale of standard deviation (SD) units. The stimuli used in the present study were pseudo-randomly drawn from a pool of 300 faces constructed from 100 distinct facial identities that varied along the dimension of trustworthiness at three different levels. All 100 facial identities were used, though only a subset was pseudo-randomly selected from each trustworthiness condition: 40 low trustworthy faces were selected from the 100 faces in the −3 SD data set; 60 neutral faces were selected from the 100 faces in the 0 SD data set; 40 high trustworthy faces were selected from the 100 faces in the 3 SD data set (see Figure 1).

During the DFTT, participants viewed brief presentations of faces that appeared to change expression. The DFTT comprised three different trial types: (1) Decreasing Trustworthiness (D; high trustworthy changing to neutral), (2) Increasing Trustworthiness (I; low trustworthy changing to neutral), and (3) Neutral (N; face identity change but no change in neutral trustworthiness level). Each trial was presented for 100 ms, with the first face (F1) shown for two screen refresh cycles (i.e., 33 ms), followed by the second face (F2) for four screen refresh cycles (i.e., 67 ms), and a 1400 ms intertrial interval (ITI). Thus, a new stimulus appeared every 1500 ms. This is essentially the same presentation speed as traditional digital video recording and gives the appearance of human-like movement on the face. During stimulus presentation, face identity change was not explicitly apparent, but the facial features appeared to subtly change expression.

Each of the F1 identities was always paired with a different identity at F2 in a pseudorandom fashion. All 100 face identities were used at F1 and 40 identities were recycled through to create a total of 140 trials, with the requirement that no F1 identity was ever
shown twice for the same condition (e.g., if an identity was shown as a neutral expression at F1, it would either be shown again later as a high or low trustworthy face), and never appeared in two trials in a row. Notably, because the F2 faces were always neutral, both of the primary conditions reflect change from extremes in trustworthiness (high or low) toward the neutral intermediate appearance.

During the fMRI scan, the DFTT was presented in alternating 30-second blocks of the primary conditions flanked by 15 seconds of a crosshair fixation point (+) at either end of the task. The total duration of the task was 240 seconds with the following block order: +, N, D, I, N, I, D, N, +. Each of the seven 30-second blocks presented 20 trials (out of 140 trials total). To ensure that participants remained engaged with the task, they were required to make a simple button response with their dominant hand as quickly as possible each time the stimulus appeared on the screen.

**Neuroimaging parameters**

Participants underwent neuroimaging on a Tim Trio 3T scanner (Siemens, Erlangen, Germany) using a 12-channel head coil. Structural images were first acquired using a T1-weighted 3D MPRAGE sequence (TR/TE/flip angle = 2.1 s/2.25 ms/12°) over 128 sagittal slices (256 × 256 matrix) and a slice thickness of 1.33 mm (voxel size = 1 × 1 × 1.33 mm). T2*-weighted functional MRI scans were collected over 43 transverse slices (3.5 mm thickness, 0 skip) using an interleaved sequence (TR/TE/flip angle = 3.0 s/30 ms/90°), with 80 images collected per slice. Data were collected with a 22.4 cm field of view and a 64 × 64 acquisition matrix.

**Image processing**

The data were preprocessed and analyzed in SPM8 (http://www.fil.ion.ucl.ac.uk/spm/). According to standard algorithms, raw images were realigned to the first image in the series, unwarp, coregistered to each participant’s high-resolution anatomical image, spatially normalized to the stereotaxic coordinate system of the Montreal Neurological Institute (MNI), spatially smoothed using an isotropic Gaussian kernel of 6 mm full-width at half-maximum (FWHM), and resliced to 2 × 2 × 2 mm voxels. The time series data were convolved with the SPM8 canonical hemodynamic response function, the AR(1) option was used to correct for serial autocorrelation, and low-frequency confounds were removed with the standard 128-second high-pass filter. Individual scans were visually inspected using the Artifact Detection Tool (http://www.nitrc.org/projects/artifact_detect/). Scan volumes exceeding 3 SD in mean global intensity or scan-to-scan motion that exceeded 1.0 mm were regressed out of the first-level analysis as a nuisance covariate.

**Statistical analysis**

For each participant, a general linear model was created to identify the regions showing greater task-related activation to the three primary task conditions, including the Decreasing Trustworthiness, Neutral Trustworthiness, and Increasing Trustworthiness blocks compared to the implicit baseline. Next, contrasts were created by comparing the Decreasing Trustworthiness > Neutral, Increasing Trustworthiness > Neutral, and Decreasing Trustworthiness > Increasing Trustworthiness conditions. The contrast images created from this analysis for each participant were carried forward as the dependent variables within second-level random effects regression analysis models with EI score as the predictor variable. Separate regression models were created for the EQ-i and MSCEIT predictors to examine the association between emotional intelligence and brain responses to changing levels of trustworthiness. Finally, based on the lack of amygdala findings for some of the a priori analyses, we undertook a series of additional post-hoc quadratic trend analyses to explore the possibility that some key regions might respond to trustworthiness in a curvilinear manner. Based on our a priori hypotheses, bilateral search territories including the primary emotional regulation and emotional response nodes of the SMC were created using the Wake Forest University PickAtlas Utility (Maldjian, Laurienti, Kraft, & Burdette, 2003) and the boundaries defined by the Automated Anatomical Labeling Atlas (Tzourio-Mazoyer et al., 2002). We focused on the bilateral gyrus rectus, ACC, and amygdala and insula bilaterally. Analyses were subjected to small volume correction for multiple comparisons within each search territory at p < .001 (uncorrected), p < .01, false discovery rate (FDR) corrected, k (extent) ≥ 10 contiguous voxels.

**RESULTS**

**Primary comparisons**

As evident in Table 1 and Figure 2, the Decreasing Trustworthiness > Neutral comparison was associated with significant activation within several regions of
TABLE 1
Locations of maximally activated voxels during primary trustworthiness comparisons

<table>
<thead>
<tr>
<th>Comparison region</th>
<th>Cluster size (voxels)</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>SPM</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreasing trustworthiness &gt; Neutral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R insula</td>
<td>16</td>
<td>46</td>
<td>-4</td>
<td>-6</td>
<td>3.83</td>
<td></td>
</tr>
<tr>
<td>Gyrus rectus</td>
<td>13</td>
<td>0</td>
<td>38</td>
<td>-16</td>
<td>3.68</td>
<td></td>
</tr>
<tr>
<td>R amygdala</td>
<td>10</td>
<td>24</td>
<td>2</td>
<td>-14</td>
<td>3.62</td>
<td></td>
</tr>
<tr>
<td>R insula</td>
<td>17</td>
<td>36</td>
<td>-20</td>
<td>12</td>
<td>3.55</td>
<td></td>
</tr>
<tr>
<td>Increasing trustworthiness &gt; Neutral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L amygdala</td>
<td>14</td>
<td>-20</td>
<td>-2</td>
<td>-20</td>
<td>4.81</td>
<td></td>
</tr>
<tr>
<td>R insula</td>
<td>40</td>
<td>34</td>
<td>-10</td>
<td>16</td>
<td>4.10</td>
<td></td>
</tr>
<tr>
<td>Gyrus rectus</td>
<td>15</td>
<td>0</td>
<td>30</td>
<td>-16</td>
<td>3.94</td>
<td></td>
</tr>
</tbody>
</table>

Notes: All analyses significant at $p < .001$, uncorrected; $p < .10$ (FDR, small volume corrected). R, right; L, left.

Within the hypothesized search regions, we found that Total EQ-i and subscale scores were not associated with functional activation in response to the Decreasing Trustworthiness or Increasing Trustworthiness conditions or the primary condition contrasts.

**Bar-On EQ-i correlations**

Total scores on the MSCEIT were not significantly correlated with activation during the Increasing Trustworthiness condition, but were positively correlated with a cluster of 22 activated voxels within the right vmPFC (i.e., gyrus rectus) [$x = 6, y = 32, z = -16, t(37) = 4.37, p = .09$ (FDR small volume corrected), during the Decreasing Trustworthiness condition (see Figure 3). Additionally, the beta parameters for each participant were extracted from the activated cluster region and correlated with the two area and four branch scores of the MSCEIT to identify the components of EI that contributed most to the observed effects. Only correlations below $p < .005$ are interpreted to avoid inflation of type I error. As detailed in Table 2, the Strategic EI area scores and the Understanding Emotions branch scores were found to correlate positively with the activated cluster within the vmPFC.

Additionally, we examined the correlation between MSCEIT scores and the primary condition contrasts. Whereas MSCEIT scores were unrelated to responses to the Increasing Trustworthiness > Neutral and Decreasing Trustworthiness > Neutral contrasts, MSCEIT scores were found to correlate positively with activation within the emotional regulation region of rostral ACC during the Decreasing versus Increasing Trustworthiness contrast (see Figure 3b). This cluster was located directly rostral to the genu of the corpus callosum in the right hemisphere [$x = 14, y = 44, z = 12, t(37) = 4.05, p = .07$ (FDR small volume corrected), with a cluster extent of 25 voxels. No other regions within the search territories were associated with MSCEIT scores. There were no significant correlations associated with the reverse contrast (i.e., Increasing Trustworthiness versus Decreasing Trustworthiness). Again, the beta parameters were extracted from the activated cluster region and correlated with MSCEIT subscale scores. This analysis...
Figure 3. Sagittal brain slices showing significant clusters of activation that correlated with EI, $p < .10$ (small volume corrected), $k \geq 10$. (a) Total scores on the MSCEIT were positively correlated with responses of the ventromedial prefrontal cortex (vmPFC) for the contrast of Decreasing Trustworthiness versus implicit baseline (left) [$x = 6$, $y = 32$, $z = -16$]. For visualization purposes, the scatterplot (right) shows the relationship between MSCEIT scores and the first eigenvariate extracted for the entire correlated cluster. (b) Total EI scores on the MSCEIT were positively correlated with responses within the rostral ACC (rACC) for the contrast of Decreasing versus Increasing Trustworthiness (left) [$x = 14$, $y = 44$, $z = 12$]. For visualization purposes, the scatterplot (right) shows the relationship between MSCEIT scores and the first eigenvariate extracted for the entire correlated cluster.

showed that the rostral ACC cluster was significantly correlated with the two area scores of Experiential and Strategic EI (see Table 2).

Nonlinear responses

Because of the important role of the amygdala in social and emotional processing of facial expressions and recent evidence suggesting that the amygdala might show a nonlinear pattern of responses to facial trustworthiness (Said, Baron, & Todorov, 2009), we undertook a post-hoc analysis to examine potential nonlinear responses of the hypothesized neurocircuitry in the present sample. A test for quadratic trend in the data was evaluated across the three conditions of Increasing Trustworthiness, Neutral, and Decreasing Trustworthiness. Table 3 presents the results of the test for quadratic trend. As evident in Figure 4, significant quadratic trend was found for responses within the right amygdala, vmPFC, and right insular cortex, suggesting significantly greater responses within these regions to images showing either Increasing or Decreasing Trustworthiness relative to Neutral images.

DISCUSSION

The ability to detect dynamic changes in facial cues signifying the intentions of others is vital to human survival. Consistent with prior work (Winston et al., 2002), we found that changes in facial cues reflecting trustworthiness were associated with increased responsiveness of key regions of the SMC, including the vmPFC, amygdala, and insula. We also found that in comparison to a condition of no change in facial...
Correlations between emotional intelligence subscales and cluster activation within the vmPFC and rostral ACC

<table>
<thead>
<tr>
<th>Emotional intelligence scale</th>
<th>fMRI cluster correlation (SPM t)</th>
<th>vmPFC [6, 32, −16]</th>
<th>rostral ACC [14, 44, 12]</th>
</tr>
</thead>
<tbody>
<tr>
<td>EQ-i total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intrapersonal Management</td>
<td>101.44 (15.76)</td>
<td>.317</td>
<td>.158</td>
</tr>
<tr>
<td>Stress</td>
<td>104.26 (15.66)</td>
<td>.166</td>
<td>.217</td>
</tr>
<tr>
<td>Management</td>
<td>103.31 (12.41)</td>
<td>.168</td>
<td>.138</td>
</tr>
<tr>
<td>EQ-i total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiential</td>
<td>105.92 (14.75)</td>
<td>.364</td>
<td>.448*</td>
</tr>
<tr>
<td>Perceiving</td>
<td>105.56 (13.89)</td>
<td>.183</td>
<td>.341</td>
</tr>
<tr>
<td>Facilitating</td>
<td>104.44 (14.39)</td>
<td>.426</td>
<td>.414</td>
</tr>
<tr>
<td>Strategic</td>
<td>99.18 (9.67)</td>
<td>.595*</td>
<td>.451*</td>
</tr>
<tr>
<td>Understanding</td>
<td>100.69 (11.89)</td>
<td>.600*</td>
<td>.390</td>
</tr>
<tr>
<td>Managing</td>
<td>97.18 (8.28)</td>
<td>.413</td>
<td>.420</td>
</tr>
</tbody>
</table>

Note: *p < .005

Locations of maximally activated voxels during analysis of quadratic trend across increasing, neutral, and decreasing trustworthiness conditions

- **Region**: MNI coordinates
  - **Cluster size (voxels)**: x, y, z, SPM t

<table>
<thead>
<tr>
<th>Region</th>
<th>Cluster size (voxels)</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>SPM t</th>
</tr>
</thead>
<tbody>
<tr>
<td>R insula</td>
<td>27</td>
<td>46</td>
<td>−4</td>
<td>−6</td>
<td>4.41</td>
</tr>
<tr>
<td>R insula</td>
<td>66</td>
<td>36</td>
<td>−10</td>
<td>18</td>
<td>3.86</td>
</tr>
<tr>
<td>Gyrus rectus</td>
<td>30</td>
<td>0</td>
<td>30</td>
<td>−16</td>
<td>3.65</td>
</tr>
<tr>
<td>R amygdala</td>
<td>19</td>
<td>24</td>
<td>0</td>
<td>−16</td>
<td>3.44</td>
</tr>
</tbody>
</table>

Notes: All analyses significant at p < .001, uncorrected; p < .10 (FDR, small volume corrected). R, right; L, left.

trustworthiness, the activation of these SMC regions was increased regardless of whether the changes in facial attributes involved decreasing or increasing levels of trustworthiness. Given the importance of social trustworthiness judgments to human survival, we further hypothesized that this capacity might be directly related to the construct of EI, a complementary form of intelligence that has been posited to depend critically on the underlying neural system of the SMC (Bar-On et al., 2003). We found that higher scores on one of two standardized and widely used measures of EI were associated with increased activation of specific nodes of the SMC in response to facial feature changes indicative of decreasing trustworthiness during fMRI. Whereas scores on the EQ-i, a self-report Trait measure of EI, were unrelated to responsiveness of the SMC to changing trustworthiness, better performance on the MSCEIT, an Ability measure of EI, was associated with increased responsiveness of the vmPFC and rostral ACC to these same dynamic changes in facial cues signifying untrustworthiness. Other regions comprising the SMC were not significantly correlated with either index of EI during this task. These findings provide support for the hypothesized role of some components of the SMC in EI, while emphasizing in particular the role of discrete regions of the medial prefrontal cortex and ACC in these capacities.

The SMH posits a central role of the vmPFC in integrating somatic emotional signals with ongoing cognition to guide decision-making (Damasio, 1994, 1996). Indeed, Bar-On and colleagues have suggested that the vmPFC is a critical node of the SMC involved in EI (Bar-On et al., 2003). Presently, we found that the responsiveness of the vmPFC to dynamic facial cues indicating decreasing trustworthiness was positively correlated with MSCEIT Total EI, Strategic EI, and the Understanding Emotions scale. Our finding that individuals with higher MSCEIT scores showed greater responsiveness of the vmPFC to subtle facial displays indicative of potential threat or dubious character is consistent with a large body of neuroscience evidence pointing to the role of that region in emotional appraisal and emotion regulation. For instance, the process of making inferences about the intentions and emotional states of others, a capacity known as Theory of Mind (ToM), is correlated with increased gray matter volume (Lewis, Rezaie, Brown, Roberts, & Dunbar, 2011) and increased functional activation within the vmPFC (Sebastian et al., 2012). Dysfunction of the vmPFC, whether through actual brain lesions (Leopold et al., 2012) or via disruption of ongoing activity by slow repetitive transcranial magnetic stimulation (rTMS) (Leventhal, Shamay-Tsoory, Zangen, & Levkovitz, 2012), also impairs affective ToM performance. Similarly, some evidence suggests that processing of the vmPFC can be disrupted by naturally occurring stresses such as sleep deprivation (Thomas et al., 2000), a process that has been shown to impair emotionally guided moral judgments (Killgore, Killgore, et al., 2007), risky decisions (Killgore, Balkin, & Wesensten, 2006), and Trait EI (Killgore, Kahn-Greene, et al., 2007).

Interestingly, we found that the vmPFC responded to changes in facial characteristics indicating either decreasing or increasing trustworthiness. Decreasing
trustworthiness was associated with increased activation of a cluster within the gyrus rectus that was centered only about 8 mm anterior to the cluster associated with viewing faces showing increasing trustworthiness. Furthermore, post-hoc analyses revealed that a cluster encompassing this same region showed a quadratic pattern of activation, responding to changes in trustworthiness in either direction. Some evidence suggests that the vmPFC represents the reward value of stimuli and plays a role in learning when reinforcement contingencies have changed (Blair, 2008). Kringelbach and Rolls propose that the primary role of the medial orbitofrontal cortex is to represent the reward value of stimuli and to identify when stimuli are no longer reinforcing (Kringelbach & Rolls, 2004), which corresponds well with our findings that this medial prefrontal region was activated when the target faces changed in level of trustworthiness, regardless of whether that change was increasing or decreasing. The vmPFC is also associated with emotional control, including voluntary regulation of negative affect and the corresponding dampening of amygdala responses (Urry et al., 2006). Importantly, the vmPFC has been shown to play a role in the maintenance of extinction memory following fear conditioning in humans (Milad et al., 2007), leading to inhibition of fear responses when encountering a previously feared stimulus (Milad & Quirk, 2002). A recent meta-analysis of neuroimaging studies also showed that patients with posttraumatic stress disorder (PTSD) show abnormal deactivations of the vmPFC (Etkin & Wager, 2007). These findings suggest that the vmPFC may be a key component of resilience and the ability to sustain mental and emotional health following exposure to traumatic events. Our results suggest that this same resilience system is engaged to a greater extent during facial trustworthiness assessments among individuals...
showing higher Ability EI, as measured by the MSCEIT.

In addition to the vmPFC, a second key region of the SMC, the amygdala, was also activated by dynamic facial cues related to trustworthiness. Direct contrasts between each dynamic trustworthiness condition versus the neutral condition revealed left amygdala activation to Increasing Trustworthiness and right amygdala activation to Decreasing Trustworthiness. This is consistent with prior research showing that the process of evaluating facial trustworthiness activates the amygdala (Engell, Haxby, & Todorov, 2007; Rule, Krendl, Ivcevic, & Ambady, 2013; Winston et al., 2002), and with a large literature suggesting that the amygdala is involved in detecting facial cues associated with threat and fear (Killgore & Yurgelun-Todd, 2004, 2005; Phelps et al., 2001; Whalen et al., 1998), as well as other emotional expressions (Fitzgerald, Angstadt, Jelsone, Nathan, & Phan, 2006). Furthermore, such responsiveness of the amygdala to trustworthiness information appears to be more strongly correlated with facial features that are commonly agreed upon by consensus raters as a signal of untrustworthiness than idiosyncratic judgments unique to the individual perceiver (Engell et al., 2007; Rule et al., 2013). Here, we used a standardized set of facial identities that varied on structural facial features that had been previously shown to covary with consensus ratings of trustworthiness (Oosterhof & Todorov, 2008), so we are reasonably confident that the amygdala responses we observed are associated with the differing levels of trustworthiness of the faces. However, it is important to consider that there may be other factors that may contribute to how the facial stimuli were interpreted. Although all of the computer-generated face stimuli used in the present study were designed to display a "neutral" emotional expression, there is some evidence to suggest that structural facial features that resemble emotional expressions can actually affect trait judgments in a systematic manner (Said, Sebe, & Todorov, 2009). For example, Said and colleagues (2009) compared human trait ratings of neutral faces to a computerized face classification system to identify features in the same faces that resembled particular emotions. They found that neutral faces tended to be rated as more positive if they had structural features that resembled expressions of happiness, while features that resembled expressions of anger tended to be judged as more threatening (Said, Sebe, et al., 2009). This tendency to overgeneralize emotions to neutral expressions based solely on the structural features of the face has been shown to affect complex impression formation (Adams, Nelson, Soto, Hess, & Kleck, 2012) and could have contributed to the current findings by giving the visual impression of changing emotion rather than changing trustworthiness per se. Additional research that disentangles these components will be necessary to provide further clarification.

The present findings also need to be considered in light of recent findings suggesting that amygdala responses to facial trustworthiness may not follow a linear pattern (Said, Baron, et al., 2009). Notably, Said, Baron, and Todorov (2009) demonstrated that amygdala responses to facial trustworthiness cues showed a quadratic rather than linear trend, with greater responsiveness to faces judged to be at the extremes of perceived trustworthiness (i.e., either high or low) (Said, Baron, et al., 2009), a finding that has since been replicated (Mattavelli, Andrews, Asghar, Towler, & Young, 2012). Accordingly, we conducted a post-hoc analysis of our data to test for nonlinear responses. Our analysis also showed this quadratic pattern for the amygdala, as well as for other SMC regions such as the vmPFC and insula when perceiving facial movement communicating information about potential trustworthiness. Overall, changes in trustworthiness in either direction led to increased activation within specific regions of the SMC, including the amygdala, vmPFC, and insula. In fact, there was no significant difference in the responsiveness of SMC regions when the Increasing and Decreasing Trustworthiness conditions were directly contrasted, suggesting similar levels of activation.

Although the hypothesized regions showed similar levels of increased activation to both trustworthiness conditions, it was also of interest to examine whether the differential response to decreasing versus increasing trustworthiness of faces might be associated with EI. We found that MSCEIT scores were positively correlated with differential activation of the rostral ACC to displays of decreasing versus increasing trustworthiness. This is important, as the rostral ACC is a brain region that is strongly implicated in error detection (Bush, Luu, & Posner, 2000; Taylor et al., 2006), emotional control (di Pellegrino, Ciaramelli, & Ladavas, 2007), assessing affective salience (Klumpp et al., 2011), and resolving emotional conflict (Etkin et al., 2006). Activation of the rostral ACC is associated with enhanced processing of threatening faces when attentional resources are limited (De Martino, Kalisch, Rees, & Dolan, 2009). Abnormal responses within the rostral ACC have also been reported in a number of psychopathological conditions involving emotional dysregulation such as depression (Cooney, Joormann, Eugene, Dennis, & Gotlib, 2010), posttraumatic stress disorder (Hopper, Frewen, van der Kolk, & Lanius, 2007; Kim et al., 2008), and high trait anxiety (Klumpp et al., 2011). There is evidence to suggest
that the rostral ACC is functionally connected with the amygdala, and that increased rostral ACC activation is frequently associated with corresponding reduction of amygdala responses (Etkin et al., 2006). In our study, we used a task that assesses brain responses to dynamic changes in facial trustworthiness, a social signal that could have important survival implications. This change in the target expression from one of high trustworthiness to one of lesser trustworthiness would be expected to require a rapid reassessment of the intention of the target face, leading to engagement of error detection and affective conflict monitoring regions of the rostral ACC once an initial face assessment was determined to be incorrect. Our finding that increasing rostral ACC activation to these cues correlated with higher scores on the MSCEIT is consistent with the putative role of this region in assessing affective salience, resolving affective conflict, and preparing the individual for a potential response. These findings suggest that individuals with higher Ability EI, including both the Experiential and Strategic aspects, are more sensitive and responsive to these subtle facial cues within this key affective regulating region, potentially conferring a survival advantage.

When considered together, the present findings suggest that greater Ability EI is associated with increased responsiveness of the vmPFC region to dynamic facial cues that could communicate the need for increased concern, vigilance, and a potential behavioral response. Higher scores on Ability EI and, in particular, subscales assessing the capacity to perceive, respond to, and control emotions (Experiential EI), and the ability to understand and direct emotions (Strategic EI) were associated with increased responsiveness of the rostral ACC. Because of the role of the rostral ACC in error detection and affective conflict monitoring (Etkin et al., 2006), these findings suggest that greater EI is associated with enhanced responsiveness of these error detection and response systems. However, while the present findings provide partial support to the hypothesized network of the SMC in EI as suggested by Bar-On et al. (2003), there were several regions of this system that failed to show correlated responses with either the EQ-i or MSCEIT. Specifically, although changes in facial trustworthiness were reliably associated with amygdala responses, this activation pattern did not correlate significantly with EI. This was unexpected, but could be related to the nonlinear nature of the amygdala responses, limited power to detect such relationships, or some other indeterminate aspect of our stimuli or experimental design. We did find, however, that Ability EI was reliably associated with activation within the medial prefrontal cortex and rostral ACC, suggesting that these emotion regulating and integrating regions appear to play an important role in these capacities. Further work will also be necessary to determine the behavioral implications of these findings, such as whether activation of these EI correlated regions actually confers performance advantages on other emotionally relevant tasks or is related to resilience under actual stressful circumstances. On the other hand, Trait EI was not significantly correlated with measured responses within the SMC during the trustworthiness conditions.

**CONCLUSION**

Greater EI was associated with increased responsiveness of the medial prefrontal cortex during a socially relevant dynamic face perception task, providing partial support for the role of the SMC in these capacities. Discrete nodes of the SMC, including the vmPFC and rostral ACC, were specifically correlated with Ability EI capacities, while Trait EI was not significantly related to the responsiveness of the hypothesized regions during dynamic facial displays communicating trustworthiness information. Overall, systematic differences in EI capacities appear to be significantly related to the responsiveness of higher order emotion assessment and regulation regions of the medial prefrontal cortex and rostral anterior cingulate.

Original manuscript received 21 November 2012
Revised manuscript accepted 16 May 2013
First published online 26 June 2013

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