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Nancy S. Koven
Bates College

Robert M. Roth
Dartmouth College

Matthew A. Garlinghouse
Dartmouth College

Laura A. Flashman
Dartmouth College

Andrew J. Saykin
Indiana University School of Medicine

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Regional gray matter correlates of perceived emotional intelligence

Nancy S. Koven,[1] Robert M. Roth,[2,3] Matthew A. Garlinghouse,[2] Laura A. Flashman,[2,3] and Andrew J. Saykin[4]
[1]Program in Neuroscience, Department of Psychology, Bates College, Lewiston, ME 04240, USA, [2]Brain Imaging Laboratory, Department of Psychiatry, Dartmouth Medical School/DHMC, One Medical Center Drive, Lebanon, NH 03756-0001, USA, [3]New Hampshire Hospital, 36 Clinton Street, Concord, NH 03301, USA, and [4]Center for Neuroimaging, Department of Radiology, Indiana University School of Medicine, Indianapolis, IN 46202, USA

Coping with stressful life events requires a degree of skill in the ability to attend to, comprehend, label, communicate and regulate emotions. Individuals vary in the extent to which these skills are developed, with the term 'alexithymia' often applied in the clinical and personality literature to those individuals most compromised in these skills. Although a frontal lobe model of alexithymia is emerging, it is unclear whether such a model satisfactorily reflects brain-related patterns associated with perceived emotional intelligence at the facet level. To determine whether these trait meta-mood facets (ability to attend to, have clarity of and repair emotions) have unique gray matter volume correlates, a voxel-based morphometry study was conducted in 30 healthy adults using the Trait Meta Mood Scale while co-varying for potentially confounding sociodemographic variables. Poorer Attention to Emotion was associated with lower gray matter volume in clusters distributed primarily throughout the frontal lobe, with peak correlation in the left medial frontal gyrus. Poorer Mood Repair was related to lower gray matter volume in three clusters in frontal and inferior parietal areas, with peak correlation in the left anterior cingulate. No significant volumetric correlations emerged for the Clarity of Emotion facet. We discuss the localization of these areas in the context of cortical circuits known to be involved in processes of self-reflection and cognitive control.

Keywords: perceived emotional intelligence; trait meta-mood; voxel based morphometry; neuroimaging; alexithymia

INTRODUCTION

Coping with stressful life events requires a degree of skill in the ability to attend to, comprehend, label, communicate and regulate emotions. These emotion-processing competencies, which are often situated within the theoretical framework of emotional intelligence, facilitate one's ability to utilize the information provided by emotions adaptively across social contexts (Salovey *et al.*, 1995). Individuals vary in the extent to which these skills are developed, with the term 'alexithymia' often applied in the clinical and personality literature to those individuals most compromised in these skills. Alexithymia, coined by Sifneos (1972) from the Greek *alexis* and *thymos* (literally 'no words for emotion'), is considered a normally-distributed, multi-dimensional personality trait whose affective deficits include inattention to and/or blunting of emotions, an inability to distinguish feelings from bodily sensations of arousal, difficulty labeling and describing emotions to others, and inappropriate emotional outbursts consistent with poor emotion regulation (Czernecka and Szymura, 2008).

Although some theorists maintain that the superordinate categories of 'emotional intelligence' and 'alexithymia' are functionally independent of one another (for discussion, see Parker *et al.*, 2001), others question the coherence of these constructs and suggest, instead, that adequate construct and discriminant validity will be found in more narrowly-defined individual differences of trait-meta mood competencies (Coffey *et al.*, 2003). When decomposing these broad constructs into discrete facets, researchers have found unique sets of external behavioral and cognitive correlates (Coffey *et al.*, 2003; Koven and Thomas, 2010). However, less is known about whether these facets have unique brain correlates.

Much of our existing knowledge about relationships between perceived emotional intelligence and functional and structural brain patterns comes specifically from the alexithymia literature, in which clinical samples have been indentified using alexithymia measures like the Toronto Alexithymia Scale (TAS-20). Neuroimaging research implicates brain pathology in alexithymia, with numerous theoretical models proposed to account for these results. Bermond and colleagues (2006) suggest that alexithymia could involve malfunctioning of the right hemisphere or, alternatively, a hyperactive left hemisphere. Additionally, abnormalities of the corpus callosum have been identified, with a study by Zeitlin and colleagues (1989) finding a strong relationship between alexithymia score and lack of bidirectional interhemispheric transfer.

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Correspondence should be addressed to Nancy S. Koven, PhD, Program in Neuroscience, Bates College, 4 Andrews Road, Lewiston, ME 04240, USA. E-mail: nkoven@bates.edu

To date, however, the majority of brain-based research on alexithymia suggests frontal lobe pathology, including the prefrontal cortex (PFC) and anterior cingulate cortex (ACC). For example, data from patients with ventromedial PFC (Shamay-Tsoory *et al.*, 2003) and orbitofrontal (Hornak *et al.*, 2003) lesions suggest that alexithymia-like deficits can be acquired after brain injury. Using fMRI to study emotion processing in alexithymic compared to non-alexithymic participants, Moriguchi and colleagues (2007) found reduced activation in the left dorsolateral PFC, dorsal pons, cerebellum, and the left caudal ACC, as well as increased activation in the right insula and inferior frontal gyrus. Using PET, Kano *et al.* (2003) found a negative correlation between alexithymia score on the TAS-20 and regional blood flow in the right superior and inferior PFC, orbitofrontal cortex (OFC), and parietal lobe during viewing of negative emotional facial stimuli. Other studies highlight the role of the ACC, with alexithymia known to result after ACC lesions (Lane *et al.*, 1997; Hornak *et al.*, 2003) and to be associated with both right (Gündel *et al.*, 2004) and left ACC volume anomalies (Borsci *et al.*, 2009).

While it seems clear that a frontal lobe model of alexithymia is emerging, it is unclear whether such a model satisfactorily reflects brain-related patterns associated with perceived emotional intelligence at the facet level. Further neuroimaging research is needed to provide greater specificity into the component processes associated with trait meta-mood skills. Construct multidimensionality can make interpretation of brain data complicated; volumetry studies on alexithymia populations to date (Borsci *et al.*, 2009), for example, have used a single composite score in order to quantify alexithymia (e.g. the TAS-20 total score) as opposed to using theoretically- or empirically-derived subscales. In the present study, we used the Trait Meta-Mood Scale (TMMS) to evaluate individual facets of perceived emotion-processing competency, specifically the degree to which one pays attention to emotion, has clarity of emotion, and can repair negative mood states. To control for the effects of confounding variables, we chose a sample of community adults who were free of neurological and psychiatric conditions for which alexithymia is among the known sequelae (Becerra *et al.*, 2002) and considered potentially-confounding covariates of gender, age, education level, and depressive symptoms.

In order to assess gray matter volume correlates of perceived emotional intelligence, we utilized voxel-based morphometry (VBM), the goal of which is to identify local differences in brain volume on a voxel-by-voxel basis across the entire brain (Mechelli *et al.*, 2005). We hypothesized that volume correlates would emerge in emotion-processing brain areas identified in previous research that measured alexithymia as a superordinate variable: ACC, anterior insula, OFC, middle temporal gyrus, superior temporal sulcus, and precuneus (Borsci *et al.*, 2009). Of relevance to our focus on trait meta-mood facets specifically, we further hypothesized that gray matter correlates of attention to one's emotions would include regions needed to attend to interoceptive and exteroceptive affective stimuli such as ventromedial PFC, middle frontal gyrus, dorsal ACC, inferior frontal cortex, and anterior insula (Mohanty *et al.*, 2007; Pollatos *et al.*, 2007; Van Den Bos *et al.*, 2007; McRae *et al.*, 2008; Pessoa, 2009). We expected that clarity of emotion would have VBM correlates in the right ventrolateral PFC, a region known to be directly involved in affective labeling and indirectly involved in inhibiting amygdala activity to negative emotional stimuli (Lieberman *et al.*, 2007). Lastly, we postulated that gray matter correlates of the ability to repair one's mood would include areas needed for cognitive control in the context of emotional stimuli such as OFC and rostral ACC (Ochsner and Gross, 2005; Mohanty *et al.*, 2007). Given that the majority of previous alexithymia research indicates inverse relationships between degree of emotion-processing deficits and structural size (although, see Gündel *et al.*, 2004) or functional activity of brain regions, we anticipated that smaller volumes would be associated with lower TMMS subscale scores.

METHODS

Participants

Participants consisted of 30 healthy, right-handed adults (14 males; 16 females) recruited through advertisements in local newspapers and workplaces. Participants were excluded if they had any past or current psychiatric illness as determined using the Structured Clinical Interview for DSM-IV-Non Patient version (American Psychiatric Association, 1994) or history of neurological disorder (e.g. epilepsy, traumatic brain injury, neurodegenerative disorders and cerebrovascular disease), mental retardation, or significant systemic medical illness. After complete description of the study, written informed consent was obtained following a protocol approved by the Dartmouth College Committee for the Protection of Human Subjects. Table 1 presents participant characteristics.

Table 1 Demographic and psychological characteristics of sample

	Mean	SD	Range	%
Gender (% women)				53
Age (years)	30.0	10.9	18–52	
Education (years)	15.6	1.7	12–19	
TMMS: Attention	49.8	7.4	30–62	
TMMS: Clarity	45.0	6.7	28–55	
TMMS: Repair	23.7	5.1	10–30	
BDI-II total score	4.0	5.0	0–19	

Note: TMMS = Trait Meta-Mood Scale; BDI-II = Beck Depression Inventory, Second Edition.

Psychological measures

We chose the TMMS as our measure of individual differences in perceived emotional intelligence as its subscales reflect dimensions of interest that are common across the superordinate constructs of emotional intelligence, alexithymia and mood awareness. Structurally, the TMMS is a 30-item scale that consists of three subscales: Attention to Emotion with 13 items that measure how much attention one pays to subjective feeling states (e.g. 'I pay a lot of attention to how I feel'), Clarity of Emotion with 11 items that measure one's ability to discriminate among and understand subjective feeling states (e.g. 'I am usually very clear about my feelings') and Mood Repair with six items that measure one's ability to regulate mood and repair negative feeling states (e.g. 'When I become upset, I remind myself of all the pleasures in life'). Lower scores on the TMMS subscales indicate greater impairment. After the appropriate reverse scoring, scores for each subscale can range from 13–65, 11–55 and 6–30, respectively. The TMMS has shown adequate internal consistency (full scale $\alpha = 0.82$), internal reliabilities (0.86, 0.87 and 0.82 for the three subscales, respectively), discriminant validity with related constructs of repression and neuroticism, good convergent validity with other meta-mood measures such as the Ambivalence Over Emotional Expressiveness Questionnaire, Expectancies for Negative Mood Regulation, the Self-Consciousness Scale, and Life Orientation Test and ability to predict unpleasant rumination after stress induction (Salovey *et al.*, 1995). Factor analytic research that examines the interrelatedness of the TMMS and two other frequently used measures of trait affective processing, the TAS-20 and the Mood Awareness Scale, has shown that Attention to and Clarity of Emotion are facets common to all three measures (Coffey *et al.*, 2003; Koven and Thomas, 2010).

Although the participant sample was pre-screened for diagnosable mood disorders, we assessed symptoms of depressed mood with the Beck Depression Inventory–II (Beck *et al.*, 1996a) given the finding that emotion processing skills may be affected by concurrent depression (Mattila *et al.*, 2006). The BDI-II consists of 21 items assessing severity of symptoms such as feelings of guilt and worthlessness, irritability, fatigue and changes in weight, sleep, appetite and libido over a two week period. Higher scores indicate greater depression. The BDI-II has been shown to have good one-week test-retest reliability (Pearson $r = 0.93$) (Beck *et al.*, 1996a) and high internal consistency ($\alpha = 0.91$) (Beck *et al.*, 1996b).

MRI data acquisition

Scans were acquired using a GE Signa 1.5-T Horizon LX magnet with echo speed gradients using a standard RF head coil. A T_1-weighted 3D spoiled gradient echo (SPGR) coronal volume was acquired. Parameters were $TR = 25$ ms, $TE = 3$ ms, flip angle = 40 degrees, $NEX = 1$ and slice thickness = 1.5 mm, yielding 124 contiguous slices with a 24 cm field of view, and a 256×256 matrix with 0.9375 mm in-plane resolution. A fast spin echo T2-weighted scan was also acquired to screen for focal lesions or other incidental findings ($TR = 3000$, $TE = 96$ and 3 mm contiguous axial slices).

MRI data processing

Volumetric data sets were reconstructed from slice data using scripts written in Matlab (Mathworks, Inc.). VBM was performed using locally developed automated scripts implementing the optimized methods described elsewhere (Ashburner and Friston, 2000; Good *et al.*, 2001). This involved resampling SPGR data to 2 mm^3 isotropic voxels, followed by automated removal of extracerebral tissue, including the skull and meninges, and extraction of gray matter, white matter and cerebrospinal fluid maps. Steps to ensure accurate segmentation were completed. Participants whose gray matter to white matter ratio or total brain volume was greater than or less than two standard deviations from the group mean were excluded, as these could indicate problems with segmentation. Accuracy of segmentation was then visually inspected and rated for quality on a scale from 0 (poor) to 1 (good), with ratings of 0.5 or less being considered of poor quality and thus excluded from further analysis. Since the sample consisted of healthy participants, unified segmentation was completed in SPM5 via the provided tissue probability and *a priori* maps (SPM5; Wellcome Department of Imaging Neuroscience, London, UK, http://www.fil.ion.ucl.ac.uk/spm/). The resulting modulated, normalized gray matter maps were subsequently smoothed using an isotropic spatial filter with a full width, half maximum of 10 mm to help adjust for individual differences in gyral anatomy. Smoothed normalized gray matter maps were used for statistical analysis.

Statistical analyses

Statistical parametric mapping was conducted on a whole brain, voxel-by-voxel basis using the general linear model and random effects analysis as implemented in SPM5. Multiple regression analysis was used to examine the correlation between three facets of trait meta-mood (Attention to Emotion, Clarity of Emotion and Mood Repair) and gray matter volume, controlling for age, gender, education and BDI-II score. Gender was included as a covariate in the VBM analysis given previous literature detailing differential profiles of alexithymia for men and women (Lane *et al.*, 1998; Salminen *et al.*, 1999). Because alexithymia is known to increase with age (Lane *et al.*, 1998; Mattila *et al.*, 2006) and decrease with educational attainment (Lane *et al.*, 1998; Salminen *et al.*, 1999), age and years of education were included as additional demographic covariates. Finally, even though the sample of participants was non-clinical in nature with low depressive symptom scores on average (Table 1), BDI-II score was included as a covariate. A statistical threshold for significance of $P < 0.001$ (uncorrected) and a minimal spatial extent (k) of 7 contiguous voxels (mm^3) were used. The combination of uncorrected P-value and minimum spatial extent was employed in order to balance the probability of Type I and II error given the relatively small sample size, as done in prior VBM studies by our group (Saykin *et al.*, 2006; Wishart *et al.*, 2006). Data are presented in MNI atlas coordinates.

RESULTS

Table 1 provides descriptive statistics for the demographic and psychological characteristics of the sample. No gender differences in score on the three TMMS subscales were noted (all P-values = ns). Table 2 presents significant correlations between gray matter volume and the trait meta-mood facets. Poorer Attention to Emotion was associated with lower volume in 17 clusters distributed primarily throughout the frontal lobe, including the anterior cingulate cortex, with peak correlation in the left medial frontal gyrus (Figure 1a). VBM analysis revealed no significant correlations for the Clarity of Emotion facet. Finally, worse Mood Repair was related to lower volume in three clusters in frontal and inferior parietal areas, with peak correlation located in the left anterior cingulate gyrus (Figure 1b).

Table 2 Regions of low gray matter volume associated with three facets of perceived emotional intelligence based on voxel-based morphometry analysis

Region	Hemisphere	Brodmann Area	MNI coordinates			Cluster size, *k* (voxels)	*Z*-score
			x	y	z		
Attention to emotion							
Superior frontal gyrus	R	10	18	62	21	10	3.14
	R	6	11	−13	76	13	3.24
Middle frontal gyrus	R	10	33	61	7	482	3.63
Medial frontal gyrus	L	6	−11	−3	59	478	4.10
	L	6	−8	−19	56	179	3.77
	R	6	7	−17	57	202	3.63
	R	6	10	−2	63	164	3.47
Frontopolar gyrus	R	10	12	69	8	225	3.55
Lateral orbital gyrus	L	11	−42	35	−19	47	3.45
	R	11	44	41	−17	405	3.37
Medial orbital gyrus	L	11	−14	26	−22	281	3.56
	R	11	10	64	−21	10	3.33
Inferior frontal gyrus	R	45	48	30	7	11	3.25
Cingulate gyrus	L	32	−11	29	32	174	3.60
	R	32	12	39	16	18	3.24
Precentral gyrus	R	4	13	−30	67	98	3.43
Cuneus	R	18	25	−82	18	9	3.24
Clarity of emotion							
No correlations emerged							
Emotional repair							
Cingulate gyrus	L	32	−12	33	26	377	3.77
	L	10	−13	50	2	9	3.25
Supramarginal gyrus	R	40	37	−49	37	7	3.18

Note: MNI = Montreal Neurological Institute; L = left; R = right. All z-scores reflect a VBM threshold of $P < 0.001$ (uncorrected) and a minimum cluster size (k) of 7 contiguous voxels. All correlations are positive such that areas of reduced volume reported here are associated with lower self-reported ability in trait meta-mood domains. Coordinates reflect peak correlation within a cluster. Localization was done using the Talairach Daemon (Lancaster *et al.*, 2000), with Brodmann areas and anatomical labels confirmed with the Talairach and Tournoux (1988) and Duvernoy (1999) atlases.

DISCUSSION

Employing VBM in a sample of healthy adults, the results of this study indicated that at least two dimensions of perceived emotional intelligence, Attention to Emotion and Mood Repair, have distinct gray matter volume correlates. While we did find volume correlates in brain areas identified in previous research that measured alexithymia as a superordinate variable (Borsci *et al.*, 2009), including the ACC and OFC, our findings suggest that examining the neural correlates of separate facets of trait meta-mood skill provides a more nuanced view of structure-function relationships. Importantly, gray matter correlates were not artifacts of demographic or other psychological variables often relevant to emotion-processing ability, as we statistically controlled for depressive symptoms, educational achievement, gender and age, as well as screened participants for mental illness and neurological risk factors.

Attention to emotion

Given that the TMMS Attention to Emotion subscale captures the degree to which an individual directs attention to affective components of conscious experience, including interoceptive and exteroceptive stimuli, we postulated that the supportive brain circuitry would involve regions that maintain and regulate attention more broadly. Of these anticipated regions, we found that diminished Attention to Emotion correlated with lower gray matter volume in right middle frontal (BA 10), right inferior frontal (BA 45) and bilateral dorsal anterior cingulate (BA 32) gyri. We also observed diminished volume in ventromedial PFC, which is often defined as a tripartite region that includes OFC (here, bilateral lateral and medial orbital gyri, BA 11), frontopolar cortex (here, right frontopolar gyrus, BA 10), and ACC (Öngür *et al.*, 2003).

The association of Attention to Emotion with a right middle frontal gyrus cluster appears consistent with the evidence for a role of this region in sustained attention (Lewin *et al.*, 1996; Johannsen *et al.*, 1997), processing self-related body information (Hodzic *et al.*, 2009) and self-face recognition and mental state attribution (Platek *et al.*, 2004). The right inferior frontal gyrus has been shown to be engaged during inhibition of emotional distracters (Wang *et al.*, 2008) and self-evaluation in face-viewing tasks (Morita *et al.*, 2004; Platek *et al.*, 2004), the latter of which is thought to reflect self-relevance (Morita *et al.*, 2004). The dorsal ACC (BA 32) is known to be involved in attention and executive functions (for review, see Mohanty *et al.*, 2007). Dorsal ACC has extensive connections with dorsolateral PFC (Paus *et al.*, 2001), and the finding of strong functional connectivity between these two regions during an emotional Stroop task suggests that

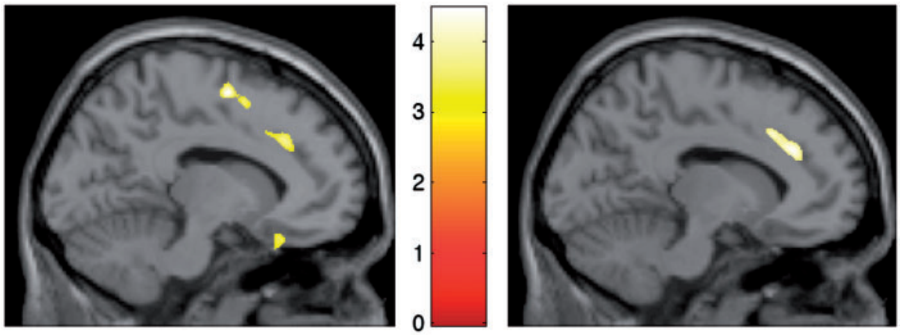

Fig. 1 Gray matter correlates across two facets of perceived emotional intelligence. Midsagittal slice showing gray matter correlates of Attention to Emotion (left panel) and Mood Repair (right panel) with threshold values of $P < .001$ (uncorrected) and $k = 7$. Table 2 shows a full list of correlating clusters.

dorsal ACC provides attentional control in the context of emotional distraction (Ochsner and Gross, 2005; Mohanty *et al.*, 2007; although, see Fellows and Farrah, 2005). In addition, the dorsal ACC is reported to aid in generating autonomic cardiovascular arousal during effortful cognitive and motor tasks in healthy adults, with acquired dorsal ACC damage associated with blunted autonomic arousal in the context of mental stress (Critchley *et al.*, 2003). Similar abnormal arousal patterns have been found in alexithymic individuals (Roedema and Simons, 1999). Of additional relevance to perceived emotional intelligence, studies of brain activation during resting state suggest that dorsal ACC activation may reflect direction of attention towards internal processes (Wicker *et al.*, 2003). Moreover, greater engagement of dorsal ACC during states of emotional arousal is associated with greater trait awareness of one's own emotional experiences (McRae *et al.*, 2008).

We also observed an association between Attention to Emotion and volumes of lateral and medial OFC. The OFC is thought to be involved in monitoring and holding information on-line, particularly when information concerns the reward value associated with stimuli and responses, with lateral OFC having a dominant role when responses to previously-rewarded stimuli must be suppressed (Elliott *et al.*, 2000). The OFC is also cast as part of a cognitive control system that shapes emotional output by appraising the emotional value of stimuli to guide an appropriate emotional response and/or by learning to associate new emotional responses with stimuli (Ochsner and Gross, 2005; Rudebeck *et al.*, 2008; Roelofs *et al.*, 2009). This would also suggest a role in Mood Repair, which was not observed. Finally, right frontopolar gyrus has been shown to be active in participants making judgments of emotional intensity during autobiographical memory retrieval, which suggests a role for this region in the elaboration and maintenance of emotional representations (Daselaar *et al.*, 2008).

In addition to these hypothesized regions, several additional clusters were associated with Attention to Emotion: right superior frontal gyrus (BAs 6 and 10), bilateral medial frontal gyrus (BA 6), right precentral gyrus (BA 4) and right cuneus (BA 18). Previous neuroimaging research has identified the superior frontal gyrus, particularly in the right hemisphere, as being jointly active during self-awareness (e.g. self-face recognition) and mental state attribution (e.g. inferring mental states of others) tasks (Platek *et al.*, 2004). Furthermore, a meta-analysis of five neuroimaging studies indicated activation of the right superior frontal gyrus when individuals are engaged in self-referential, internally-directed attention tasks (Wicker *et al.*, 2003). The medial frontal gyrus has been implicated in the social cognition literature, with studies highlighting its involvement during self-reflective and/or mentalizing tasks such as judging self-other similarities (Mitchell *et al.*, 2005), reporting the valence of one's affective state (Gusnard *et al.*, 2001), making subjective, self-referential decisions about color preference (Johnson *et al.*, 2005), rating trait adjectives for personal relevance (Kelley *et al.*, 2002), reading 'theory of mind' stories as opposed to physical stories (Fletcher *et al.*, 1995), and inspecting a spatial environment from a first-person, as opposed to third-person, perspective (Vogeley *et al.*, 2004). The precentral gyrus has been implicated in self-face recognition, which is argued to be a prerequisite for self-evaluation (Morita *et al.*, 2004). Blackwood and colleagues (2000) also identify this region as important for the representation of the self as an intentional, responsible agent. Finally, although the cuneus is not often discussed in the social cognition literature, Platek and Kemp (2009) reported evidence of cuneus activation during facial discrimination tasks (comparing kin faces to friend faces), which they suggested represents computational processing about facial familiarity and identity. While not emotion processing per se, both processes arguably require attention to the self.

Taken together, the brain regions we observed to be associated with attention to one's emotional states appear to support various aspects of meta-mood that require internally directed attention and emotionally-driven externally directed attention, particularly those that aid in self-reflection, self-identification, general awareness of one's internal experiences, attention to reward-salient stimuli, and evaluation of stimuli for emotional significance. Interestingly, evidence suggests that self-awareness and other-awareness recruit highly overlapping brain regions (Vogeley *et al.*, 2001; Decety and Chaminade, 2003; Gallup *et al.*, 2003), the proposition being that one must be able to consider one's own mental life in order to infer that of another. This idea, which is at the heart of simulation theory (for review, see Mitchell *et al.*, 2005; Stone, 2006), argues that awareness of one's mental states enables an individual to model comparable mental experiences in others. It is documented that individuals low in perceived emotional intelligence struggle to infer what others want and intend to do (Salovey *et al.*, 1995; Meins *et al.*, 2008), particularly in intimate relationships (Wastell and Taylor, 2002). Future volumetric and morphometric studies should incorporate measures of attention to one's own and to other's emotions to test whether the brain circuitry described above serves these dual roles.

It is worth noting that Attention to Emotion was correlated predominantly with regions lateralized to the right hemisphere. There is a robust literature supporting right hemisphere involvement in processing information about the self (for review, see Keenan *et al.*, 2005). Moreover, this right hemisphere system is predominated by frontal regions, including superior, middle, medial, and inferior frontal gyri (Platek *et al.*, 2004), which is a subset of the regions we found to decrease in gray matter volume with worsening attention to emotion. It is possible that many of the attention-related deficits seen clinically in alexithymia are secondary to deficiencies in these right hemisphere self-processing areas. Although Attention to Emotion correlates predominated in the right hemisphere, left hemisphere frontal lobe correlates emerged as well, which is consistent with the argument that self-awareness requires a degree of verbal self-description, a left hemisphere-biased linguistic process that differentiates one's own self from others (Faust *et al.*, 2004).

Mood repair

We postulated that gray matter correlates of the ability to repair one's mood would include areas needed for cognitive control in the context of emotional stimuli such as OFC and rostral ACC (Ochsner and Gross, 2005; Mohanty *et al.*, 2007). In contrast to these and other regions known to be involved in inhibitory control such as the inferior frontal gyrus (Cohen and Lieberman, 2010), we instead found that reduced volume in two clusters in left dorsal cingulate cortex was associated with poorer ability to repair one's mood. While the dorsal ACC is argued to be a cognitive processing area rather than an emotion processing area (Mohanty *et al.*, 2007), it is likely important for emotion regulation, or the ability to repair one's mood, given evidence of its involvement in voluntary reappraisal of negative emotion (Ochsner *et al.*, 2004; Phan *et al.*, 2005), suppression of sadness (Lévesque *et al.*, 2003), and voluntary inhibition of sexual arousal (Beauregard *et al.*, 2001).

In addition to dorsal ACC, we found an unexpected cluster in the right supramarginal gyrus (BA 40). As this is a small cluster ($k = 7$) that just meets the threshold for significance, we do not wish to overstate the importance of this region in emotion regulation. However, finding that diminished gray matter volume in this area correlates with poor Mood Repair makes sense in the context of recent neuroimaging work. The supramarginal gyrus is considered part of the inferior parietal lobe, which, in the right hemisphere specifically, is implicated in inhibitory control (Bellgrove *et al.*, 2004; Kana *et al.*, 2007) and having a sense of agency (for review, see Decety and Chaminade, 2003). Lacking a sense of agency (i.e. the state of being in action or exerting power), in combination with poor inhibitory control, may very well contribute to an inability to regulate one's emotion.

Limitations

The above findings need to be considered in the context of the limitations of the study. First, the relatively small sample size, with its associated restriction on statistical power, may partly explain why we did not uncover any gray matter clusters related to the Clarity of Emotion facet of trait meta-mood processing. Furthermore, none of the findings remained significant after correction for multiple comparisons. Again, this is likely due to limited statistical power secondary to the relatively small sample size. Nonetheless, we feel that the nature of the findings, which are largely consistent with what could be predicted based on the available literature, still makes a meaningful contribution to our understanding of perceived emotional intelligence. However, replication in a larger sample will be necessary to establish the reliability of the findings and clarify whether VBM can detect a meaningful relationship between regional brain volumes and Clarity of Emotion. Second, we selected non-clinical community participants for this investigation rather than psychiatric patients. This, along with the statistical choice of using whole-sample correlation (i.e. as opposed to using an analysis of variance approach with artificially defined high- and low-ability groups), means that our findings are better construed as individual difference patterns across the continuous variables of perceived emotional intelligence rather than as a clinically-derived profile of alexithymia. It remains unknown whether the relationships that we observed hold for individuals in various diagnostic groups for which alexithymia tends to be elevated, but we are planning to address this in future studies.

Finally, while VBM has merit for being a fully automated method by which to survey the entire brain, thereby providing a non-biased assessment of highly localized regions (Giuliani *et al.*, 2005), some argue that it is not a replacement for manual volumetric analysis with anatomically-defined regions of interest (Kubicki *et al.*, 2002). To date, only the cingulate cortex has been scrutinized in the context of alexithymia using manual volumetry

(Gündel *et al.*, 2004), and, thus, future studies will be needed to assess the relationship to volumes of other anatomical regions of interest. The current VBM results may serve as a guide for targeting regions of interest in subsequent manual volumetry studies, as well as inform the selection of regions of interest in future VBM studies of trait meta-mood processing in non-clinical and clinical populations.

CONCLUSION

To our knowledge, the present study provides the first analysis of brain-wide relationships of gray matter volume to specific dimensions of perceived emotional intelligence. Two out of three facets, Attention to Emotion and Mood Repair, have generally distinct sets of correlates. Worse Attention to Emotion is associated with lower gray matter volume in largely right-lateralized frontal lobe regions that other research has identified as important for processes of self-reflection, self-identification, general awareness of one's internal experiences, attention to reward-salient stimuli, and evaluation of stimuli for emotional significance. In contrast, worse Mood Repair is associated with decreasing volume in frontoparietal areas known to be involved in cognitive control, having a sense of agency and inhibitory control, all of which may be key to successful emotion regulation. While bearing in mind the limitations of the present study, the findings presented here indicate that neurobiological models of the related constructs of trait meta-mood, alexithymia and emotional intelligence should incorporate a more nuanced view of its component emotion-processing.

Conflict of Interest

None declared.

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