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Gray Matter Correlates of Emotional Intelligence in Incarcerated Males

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GRAY MATTER CORRELATES OF EMOTIONAL INTELLIGENCE IN INCARCERATED MALES

by

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THESIS

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DEDICATION

This thesis is dedicated to my son, Oliver, who is my daily inspiration.

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Gray Matter Correlates of Emotional Intelligence in Incarcerated Male Offenders

by

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ABSTRACT

Emotional intelligence (EI) is form of social intelligence that is important for navigating one's social environment. Deficits in these abilities have been associated negative psychological outcomes such as anxiety, substance use, and aggression. Here, we extend current literature that suggests that EI is correlated with gray matter volume (GMV) in limbic regions (e.g. insula ventromedial prefrontal cortex, anterior cingulate, and cerebellum) in healthy samples, by using voxel-based morphometry (VBM) to assess the relationship between GMV and EI. In study 1, emotional intelligence was positively correlated with GMV in the cerebellum and anterior cingulate cortex in a sample of incarcerated adult males, and in study 2, emotional intelligence was negatively correlated with GMV in the precuneus and posterior cingulate cortex in a sample of incarcerated adolescent males. In study 3, we demonstrate that age moderates the relationship between EI and GMV in these regions. Because incarcerated populations tend to experience increased rates of negative outcomes associated with reduced emotional intelligence, it is important to understand EI in this population to determine whether it is a viable target for treatments to reduce future negative outcomes, including recidivism, upon release.

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BACKGROUND AND SIGNIFICANCE

Emotions are important social cues that are critical for an individual to adaptively respond to their social environment (Keltner, Haidt, & Shiota, 2014). Thus, deficits in emotional competencies have important implications for how we interact with our surroundings. As a result, researchers have become interested in studying the construct of *emotional intelligence* (EI), a form of social intelligence which is composed of four component abilities: 1) accurately perceiving, recognizing, and expressing emotions, 2) accessing, generating, and using emotion to facilitate thought, 3) understanding emotions, and 4) managing and regulating emotion in oneself (Salovey & Mayer, 1990).

Models of EI

Two distinct models of emotional intelligence have been studied in the literature (Mayer, Roberts, & Barsade, 2008): trait EI and ability EI. Most measures assess trait EI and rely on an individual to self-report their ability to use emotions in social interactions and recognize emotions in themselves. Because trait EI models conceptualize EI as a trait, these measures show moderate correlations with other personality traits in youth and adults, such as conscientiousness, agreeableness, and extraversion (Craig et al., 2009; Ferrando et al., 2011).

Conversely, ability measures conceptualize EI within the confines of the standard criteria for a form of intelligence (Mayer, Caruso, & Salovey, 1999). Like cognitive intelligence, ability EI is measured by assessing an individual's performance on a number of tasks that are, in this case, emotionally-relevant, and comparing their performance to a standard criterion. Specifically, individuals are tested on their ability to identify facial expressions and accurately perceive and manage emotions in emotionally laden situations. Several studies have provided support for distinguishing trait and ability EI by demonstrating that ability and trait measures of EI are not highly correlated with each other and show differential relationships with personality factors and crystallized intelligence (Brackett & Mayer, 2003; Joseph & Newman, 2010; Mayer et al., 2008; Peters, Kranzler, & Rossen, 2009).

The Mayer–Salovey–Caruso Emotional Intelligence Test (MSCEIT; Mayer, Salovey, Caruso, 2002) was the first EI measure developed to assess the construct of ability EI in adults, and, subsequently, a youth version (MSCEIT-YV-R) was designed for use with adolescents ages 10–18 (Mayer, 2005). Both versions demonstrate sound psychometric properties (Mayer, Salovey, Caruso, & Sitarenios, 2003; Rivers et al., 2012). The MSCEIT measures two broad domains of emotional intelligence: (1) an experiential domain which assesses the degree to which an individual is able to perceive emotions and can use emotions to facilitate thought, and (2) a strategic domain which assesses the degree to which an individual can understand and manage emotions in oneself and others. As is true with other forms of intelligence, these abilities are thought to develop as a function of both age and cognitive maturation (Kafetsios, 2004; Mayer et al., 1999)

Psychological Correlates of Emotional Intelligence

Reduced EI is associated with many forms of psychopathology including anxiety, depression, substance use, and psychopathy, as well as other negative outcomes including aggression, difficulties in interpersonal relationships, and elevated stress levels in adults and adolescents (Brackett, Mayer, & Warner, 2004; Dawda & Hart, 2000; Edwards, Ermer, Salovey, & Kiehl, 2018; Ermer, Kahn, Salovey, & Kiehl, 2012; Fox, Bergquist, Casey, Hong, & Sinha, 2011; García-Sancho, Salguero, & Fernández-Berrocal, 2014; García-Sancho et al., 2014; Kahn, Ermer, Salovey, & Kiehl, 2016; Moriarty, Stough, Tidmarsh, Eger, & Dennison, 2001). On the other hand, increased EI has been suggested as a protective factor resulting in lower stress, better ability to maintain positive mood (J. V. Ciarrochi, Chan, & Caputi, 2000; Schutte, Malouff, Simunek, McKenley, & Hollander, 2002) and more supportive and satisfied interpersonal relationships (J. Ciarrochi, Chan, & Bajgar, 2001). Ability EI, specifically, may also serve as a protective factor among youth who have experienced traumatic events. For example, in a sample of adolescents who experienced sexual abuse, strategic EI served as a protective factor for suicidal ideation and suicide attempts (Cha & Nock, 2009). Increased EI is also associated with improved mental health, such as fewer episodes of anxiety and depression and fewer externalizing problems (Petrides, Sangareau, Furnham, & Frederickson, 2006; Siu, 2009).

Fortunately, research suggests emotional abilities can be trained and developed (Nelis, Quoidbach, Mikolajczak, & Hansenne, 2009), and, consequently, a body of literature has attempted to target emotional intelligence in treatments to improve mental health broadly. For instance, emotional intelligence training in a sample of Spanish adolescents resulted in fewer clinical symptoms up to 6 months after the intervention compared with students in a control group (Ruiz-Aranda et al., 2012). Other interventions aimed at increasing EI, have been successful at reducing aggression and increasing empathy (Castillo, Salguero, Fernández-Berrocal, & Balluerka, 2013) in adolescent boys.

Emotional Intelligence in Incarcerated Offenders

Because incarcerated populations tend to experience increased rates of negative outcomes related to EI (Atkins et al., 1999; Prins, 2014), this is an important sample to study in terms of understanding this construct in order to determine whether it is a viable target for treatments to reduce future negative outcomes, including recidivism, upon release. However, the literature is mixed regarding whether EI is impaired in offender samples. A prior study from our lab assessing ability EI and callous-unemotional traits (a downward extension of psychopathic traits assessed in youth samples) found mean levels of EI the same sample of adolescent male offenders that will be used for the current study (Kahn et al., 2016). Another study which assessed EI in a small sample of Irish adolescent detainees, a clinical psychiatric group, and a community sample found that the detainees demonstrated lower levels of trait and ability EI than the community sample, but it is worth noting that the detainees were demonstrating mean levels of ability EI and IQ whereas the community sample was showing significantly increased ability EI and IQ scores (Margaret Hayes & Reilly, 2013). This could indicate that the community sample used in this sample was not representative of a typical healthy, community sample. In another study from our lab, using the same adult sample used for the current study, incarcerated adult males were found to have lower EI than the normative sample (Ermer et al., 2012), despite having relatively preserved IQ scores. These findings, taken together, may suggest that EI in adolescent offenders is preserved, but is impaired in adult offenders. As a result, EI may be an important target for treatments in incarcerated youth to prevent future criminal behavior.

Neural Correlates of Emotional Intelligence

A small body of neuroimaging studies have suggested that social cognition and "somatic marker" networks are involved in EI, which include such regions as the ventromedial prefrontal cortex (vmPFC), amygdala, insula, and cerebellum (Bar-On, Tranel, Denburg, & Bechara, 2003; Killgore & Yurgelun-Todd, 2007; Tan et al., 2014). In a sample of Japanese university students, both positive and negative correlations with trait EI and gray matter tissue density were found. Gray matter tissue density in the right anterior insula, right cerebellum, cuneus/precuneus, medial PFC, and left frontopolar was negatively correlated with the intrapersonal factor of a self-report Emotional Intelligence Scale, while the same intrapersonal factor was positively associated with gray matter density the right superior temporal sulcus. Additionally, the Situation Management of this Emotional Intelligence Scale was negatively correlated with vmPFC gray matter density (Takeuchi et al., 2011). In another study of university students, the Monitor of Emotions subscale on a trait EI was positively correlated with gray matter volume (GMV) in the insula and OFC; the Utilization of Emotions subscale was positively correlated with GMV in the parahippocampal gyrus and negatively correlated with GMV in regions of the temporal cortex; and the Social Ability subscale was positively correlated with GMV in the vermis (cerebellum). (Tan et al., 2014) Lastly, one study found that trait EI was positively correlated with GMV in several frontal and parietal clusters, including the vmPFC, as well as the anterior cingulate cortex (ACC) bilaterally (Koven, Roth, Garlinghouse, Flashman, & Saykin, 2011). While this study had a wider age range than most that have looked at EI and gray matter (ages 18-52), the researchers used a relatively small sample that collapsed across 16 male and 14 female participants and focused on trait, rather than ability EI.

Only one study, to our knowledge has looked at the correlations between ability EI and GMV. In this study, which looked at associations between both trait and ability EI and GMV, trait EI was positively associated with bilateral ventromedial prefrontal cortex volume, while ability EI, measured by the MSCEIT, was positively associated with left insula volume (Killgore et al., 2012). While no studies, to our knowledge, have looked at the association between EI and GMV in adolescents, Killgore and colleagues found that among a sample of 16 children (aged 8 to 15), trait EI was negatively correlated with activity in the vmPFC, amygdala, anterior cingulate, and insula while viewing fearful faces and positively correlated with activity in the cerebellum, as well as temporal and occipital regions. However, it’s important to note that while these findings are informative regarding neural correlates of EI, activity during an fMRI task is not directly comparable to gray matter volume or density. It is also worth noting that this sample was younger than our adolescent age range.

Taken together, these findings suggest a relationship between trait EI and gray matter volume and density in select regions in healthy adult samples; however, the results to date are in mixed directions. Additionally, research assessing the relationship between gray matter and EI to date has been conducted in small healthy populations that combine adult male and female samples, and, have primarily focused on trait measures of EI. Thus, the relationship between ability EI and GMV remains unclear, especially in adolescents, and, to our knowledge, no studies have attempted to determine how or whether the association between gray matter and EI changes over the life span.

This study aims to extend current literature that suggests EI is correlated with GMV in somatic marker and limbic regions (e.g. vmPFC, insula, ACC, and cerebellum), by determining whether ability EI is correlated with GMV in a large sample of incarcerated adolescent and adult males using voxel-based morphometry (VBM). Additionally, we aim to determine how the relationship between emotional intelligence and gray matter volume changes as a function of age.

Importantly, although two widely-accepted measures of gray matter have been used in the literature (i.e. gray matter volume and gray matter concentration), for the purposes of this study we will focus on modulated gray matter volume, which assesses local gray matter tissue volumes correcting for effects of normalization of data to a standard template, rather than unmodulated gray matter concentration which measures local gray matter tissue density without taking into account distortions in voxel size due to normalization (Ashburner & Friston, 2000; Good et al., 2001; Mechelli, Price, Friston, & Ashburner, 2005).

STUDY 1: Gray matter correlates of emotional intelligence in incarcerated adult male offenders

INTRODUCTION

Study 1 aimed to extend current literature that suggests that emotional intelligence is correlated with GMV in somatic marker and limbic regions, namely the insula, vmPFC, ACC, and cerebellum, by determining whether ability emotional intelligence is correlated with gray matter volume and density in a sample of incarcerated adult males using voxel-based morphometry. We hypothesized that emotional intelligence would be positively correlated with GMV in the aforementioned social cognition and somatic marker regions, including the insula, ventromedial prefrontal cortex, anterior cingulate, and cerebellum (vermis). We limited our cerebellar ROI to the vermis (referred to as the limbic cerebellum) due to the literature suggesting that the vermis is associated with emotional processing and emotion regulation (Schutter & Honk, 2005).

Furthermore, we used planned post-hoc comparisons to assess whether these relationships were driven by a particular domain of emotional intelligence (i.e. strategic or experiential).

METHODS

Participants

Study 1 utilized an existing dataset of 249 incarcerated adults recruited from medium and maximum security correctional facilities in New Mexico. This research was approved by the University of New Mexico Health Sciences Center Institutional Review

Board. For this protocol, meetings were scheduled with interested participants and informed consent was obtained. Participants were informed of their right to terminate participation at any point, the lack of direct institutional benefits, and that their participation would not affect their facility status or parole. Participants received remuneration at the hourly labor wage of the facility.

Data from only male offenders were included in this sample given the sex differences in both emotional intelligence (Goldenberg, Matheson, & Mantler, 2006; Schutte et al., 1998) and GMV (Cosgrove, Mazure, & Staley, 2007; Gur et al., 1999). Participants were excluded for the following criteria: an estimated general IQ less than 70, an English reading level less than the 4th grade or equivalent, history of neurological disorders or stroke, head injury accompanied with a significant loss of consciousness, or a personal or first-degree relative with a history of psychotic disorders.

Assessments

MSCEIT

EI was assessed in adults using the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT), an ability-based emotional intelligence measure consisting of 141 self-report items. The MSCEIT provides a global EI score, along with experiential and strategic EI scores (Mayer et al., 2003).

Experiential Emotional Intelligence

Experiential EI measures an individual's ability to recognize, respond, and manipulate emotional information, and consists of two subscales: (1) perceiving emotions, and (2) using emotion to facilitate thought (Mayer, Salovey, & Caruso, 2002).

Perceiving emotions (B1) uses face and picture tasks to examine the degree to which an individual attends to emotional expressions and recognizes feelings in others. In the face task, an image of a person expressing an emotion is presented to the individual and they are asked to identify what the person is feeling based on their expression. In the picture task, images of landscapes or abstract designs are presented, and the individual is asked to rate the degree to which the presented image expresses emotions. The second subscale, using emotion to facilitate thought (B2), measures how cognitions are informed and influenced by emotions and is measured via sensation and facilitation tasks. In the sensation task, participants are provided with scenarios and asked to compare emotions to sensations (e.g., how cold or sweet a feeling of guilt may be). In the facilitation task, participants are asked to rate the utility of moods in various situations (e.g., "What mood(s) might be helpful to feel when creating new exciting decorations for a birthday party?").

Strategic Emotional Intelligence

Strategic EI assesses the ability to understand what emotions mean and manage emotions, and is also separated into two subscales (1) understanding emotion and (2) and managing emotion (Mayer et al., 2002). Understanding emotion (B3) assesses an ability to analyze emotions and understand how emotions change over time and is measured via blend and change tasks. In the blend task, participants are asked questions about how emotions combine to go from simple to complex feelings. In the change task, participants are asked to identify how emotions progress from one to another (e.g. anger into rage) from a multiple-choice list. The managing emotion subscale (B4) assesses a participant's ability to manage emotions via emotion management and emotional relation tasks. In the emotion management task, participants are asked to rate the efficacy of specific actions in obtaining a result, where one must regulate emotions. In the emotional relation task, participants evaluate the how effective particular actions are in achieving an outcome for another person.

The MSCEIT is scored online (Multi-Health Systems) and a summary report of participant scores is generated. Using the general consensus scoring method, participants' performance was judged by a general consensus criterion, established by a normative database consisting of more than 5,000 individuals. Standardized scores based on *M* = 100 (*SD* = 15) are reported.

Additional Assessments

Additional assessments were administered to assess intelligence quotient (IQ), mental illness, and traumatic brain injury.

General Intelligence:

A two subtest form of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III; Wechsler, 1997) was administered to all adult participants. The two subtests, Vocabulary and Matrix Reasoning, provides a reliable estimate of full scale IQ for the WAIS-III (Ryan, Lopez, & Werth, 1999).

Mental Illness

Adult participants were comprehensively evaluated for psychological disorder diagnoses via the Structured Clinical Interview for DSM-IV-TR Research Version, Patient Edition (SCID-I/P; First, Spitzer, Gibbon, & Williams, 1997). Participants with a history of psychosis, including Bipolar Disorder and Major Depressive Disorder with psychotic features, a history of Bipolar disorder, and/or any current disorder were excluded. Interviews were administered by trained research assistants.

Traumatic Brain Injury

A post-head injury symptoms questionnaire (adapted from King, Crawford, Wenden, Moss, & Wade, 1995) that assesses history, number, and duration of traumatic brain injuries, in addition to related symptoms was administered to all participants. Individuals who reported a traumatic brain injury with loss of consciousness of more than 1 h were excluded.

Data Acquisition

High-resolution T1-weighted structural MRI scans were acquired on the Mind Research Network Siemens 1.5T Avanto mobile scanner, stationed at the correctional facilities, using a multi-echo MPRAGE pulse sequence (repetition time = 2530 ms, echo times = 1.64 ms, 3.50 ms, 5.36 ms, 7.22 ms, inversion time = 1100 ms, flip angle = 7°, slice thickness = 1.3 mm, matrix size = 256 × 256) yielding 128 sagittal slices with an in-plane resolution of 1.0 mm × 1.0 mm. Data were pre-processed and analyzed using Statistical Parametric Mapping software (SPM12; Wellcome Department of Cognitive Neurology, London, UK; http://www.fil.ion.ucl.ac.uk/spm). T1 images were manually inspected by an operator blind to subject identity and realigned to ensure proper spatial normalization. Images were spatially normalized to the SPM12 T1 Montreal Neurological Institute (MNI) template using non-linear registration, segmented into gray matter, white matter, and cerebrospinal fluid, and modulated with the local Jacobian determinants of the non-linear transformation to preserve total volume (Ashburner &

Friston, 2000; Good et al., 2001; Mechelli et al., 2005). The modulated, normalized gray matter segments were then averaged to create a customized, study-specific template. Next, the original gray matter segments were normalized to the customized template. Finally, the images were resampled to 2 × 2 × 2 mm and smoothed with a 10 mm full-width at half-maximum (FWHM) Gaussian kernel. Voxels with a gray matter value of < .15 were excluded in order to remove possible edge effects between gray matter and white matter, following methods used in previously published work from our lab (Ermer et al., 2012).

Data Analysis

We conducted a linear regression analysis to determine whether emotional intelligence is related to GMV in somatic marker and limbic regions, such as the insula, vmPFC, ACC, and limbic cerebellum (vermis) in this sample. Because we are interested in the relationship between total emotional intelligence and GMV in these regions, as well as the relationships between the specific factors of emotional intelligence (i.e. strategic and experiential), we ran a model with total EI and planned post-hoc comparisons with the two factors of EI.

In Model 1, MSCEIT total scores were used continuously as the independent variable of interest. Volumetric analyses require a control for individual variation in total brain volume; thus, here, we included total brain volume (TBV; white matter + gray matter) as a covariate, in addition to IQ and Age.

Model 2 and Model 3 were planned post-hoc comparisons to determine whether significant relationships between total EI and GMV were driven by a particular domain of EI. These models included experiential and strategic emotional intelligence as the independent variable of interest in each model, respectively, and included the same covariates (TBV, IQ, and Age) as Model 1.

Whole Brain Analysis

As an initial exploratory analysis to test for small distributed gray matter effects, we used a program, AlphaSim (Ward, 2000), to estimate the cluster size necessary to correspond to a desired statistical threshold. A Monte Carlo simulation was conducted using AlphaSim (Ward, 2000) which determined that a 396 voxel extent at $p < .001$ uncorrected yielded a corrected threshold of $p < .05$, accounting for spatial correlations between gray matter volumes (GMVs) in neighboring voxels for Model 1, a 408 voxel extent at $p<.001$ uncorrected yielded a corrected threshold of $p<.05$ for Model 2, and a 392 voxel extent at $p<.001$ uncorrected yielded a corrected threshold of $p<.05$ for Model 3.

ROI Analysis

Because we had *a priori* hypothesis about specific regions we expected to be associated with emotional intelligence, in addition to an exploratory whole brain analysis, we conducted an ROI analysis to determine whether EI was associated with gray matter in these specific regions. Anatomical image masks based on the hypothesized regions of interest (left and right vmPFC, left and right ACC, left and right insula, and cerebellar vermis) were created using the Wake Forest University Pick Atlas Toolbox in SPM12 based on Automated Anatomical Labeling defined regions (Figure 1). We limited our cerebellar ROI to the vermis, due to the burgeoning literature suggesting that the vermis, specifically, is associated with emotion processing. For each region, a small volume correction (SVC) was applied to the area within each mask; we report the false discovery rate (FDR) correction.

RESULTS

Descriptive Statistics

The participants in this sample ranged in age from 18 to 60 (*M = 33.78, SD = 9.48)* at the time of scanning. Ethnically, participants were predominately Hispanic/Latino (55.9%). 31.2% of the sample identified as Non-Hispanic White, 6.5% as Non-Hispanic Black/African American, and 6.5% as Non-Hispanic American Indian/Alaskan Native. See Figure 2 for racial and ethnic breakdown. There was no significant racial or ethnic group differences in total EI scores in this sample, thus neither race nor ethnicity were included as covariates in our models. IQ ranged from 72-137 (*M=96.77, SD = 13.73).* See Table 1 for descriptive statistics of sample.

MSCEIT

MSCEIT scores in this sample ranged from 58 – 114 *(M=88.54, SD = 13.44).* Experiential EI scores ranged from 56 – 131 *(M=97.47, SD = 15.55)* and strategic EI scores ranged from 46 – 113 *(M=84.66, SD = 10.399).* Two individuals were excluded from final analyses due to having MSCEIT total scores more than 3 standard deviations below the mean indicating potential concerns about effort. As a result, the final sample size was 247 adult males.

Bivariate Correlations

Table 2 shows bivariate correlations for our variables of interest including MSCEIT total score, MSCEIT experiential subscale score, MSCEIT strategic subscale score, Age, IQ, and TBV. As expected, MSCEIT total score was significantly correlated with age (*r=.125, p=.050*) and IQ (*r=.460, p<.001)*. Experiential (*r=.281, p<.001*) and strategic (*r=.523, p<.001*) subscale scores were significantly correlated with IQ, and strategic subscale score (*r=.268, p<.001)* but not experiential subscale score (*r=-.046, p=.468*) was significantly correlated with age.

Model 1

Based on the cluster extent threshold (396 voxels), GMV analyses across the whole brain produced one large cluster in the limbic cerebellum (vermis) that was positively associated with MSCEIT total scores (Figure 3a, Table 3).

Small volume corrected *a prori* anatomical ROI analyses were consistent with the cluster extent whole brain analysis demonstrating that MSCEIT total score is positively correlated with GMV in the limbic cerebellum (Figure 3b, Table 4). No significant correlations were found with the left or right vmPFC, ACC, or insula.

Model 2

Based on the cluster extent threshold (408 voxels), whole-brain analyses for model 2, GMV did not show an association with MSCEIT experiential subscale score. Analyses in our *a priori* ROIs using SVC found a significant positive correlation between MSCEIT experiential subscale score and GMV in the limbic cerebellum (Figure 4, Table

4). Again, EI was not significantly correlated with GMV in left or right vmPFC, ACC, or insula.

Model 3

Similar to Model 2, in our exploratory, whole-brain analyses GMV analyses based on the cluster extent threshold (392 voxels), GMV did not show an association with MSCEIT experiential subscale score.

In contrast to models 1 and 2, SVC ROI analysis found that strategic subscale score was positively correlated with GMV (Figure 5a, Table 4) in the limbic cerebellum, as well as GMV in the left ACC (Figure 5b, Table 4) No other ROIs demonstrated significant correlations with GMV.

DISCUSSION

The current study adds to the literature on neural correlates of emotional intelligence by investigating structural correlates of EI using VBM in a sample of incarcerated men (n = 247) assessed for ability EI using the MSCEIT. This is the first study, to our knowledge, to apply VBM analyses in a large incarcerated sample.

Cluster extent analysis (using AlphaSim) across the whole brain found that ability EI is associated with increased GMV in the limbic cerebellum. This whole brain analysis also found that GMV in the limbic cerebellum is also associated with strategic, but not experiential EI. These results were largely consistent with the areas identified through the ROI analyses. In these analyses, we found that ability EI (total scores), as well as experiential and strategic EI, were associated with GMV in the limbic cerebellum.

Prior research on the cerebellum has primarily focused on its involvement in motor function; however, an increasing body of literature has begun to find evidence that the cerebellum may be involved in emotions and emotion regulation due to its afferent and efferent connections to the midbrain and limbic circuitry. Specifically, the vermis has been implicated in “disorders of emotion” such as depression and schizophrenia, in addition to demonstrating functional connections to limbic regions. (Schutter & Honk, 2005) Additionally, several structural and functional neuroimaging studies have found that regions of the cerebellum, including the vermis, were associated with emotional intelligence in adults (Takeuchi et al., 2011; Tan et al., 2014). This work provides additional evidence for the role of the cerebellum in the construct of emotional intelligence, and further supports the hypothesis that regions of the cerebellum should be considered an extension of the limbic circuitry and may be important to consider in the context of emotion recognition and emotion processing.

The anterior cingulate cortex has long been considered an integral part of the limbic circuitry and has been implicated in emotion processing, appraisal and expression of negative emotion, and generating emotional responses (Etkin, Egner, & Kalisch, 2011). Here we find evidence of increased GMV in the left ACC is associated with increased strategic EI, which involves identification (or appraisal) and management of emotions.

Unlike several prior studies of trait and ability EI, we did not find relationships between ability EI and GMV in other limbic regions including the vmPFC and insula. The differences we see between our sample and prior work could be due to sample characteristics (e.g. healthy sample vs incarcerated individuals) or other methodological differences. Although the range of scores in our sample appears consistent with prior work in this area, our sample ($M = 88.54$) scored nearly one standard deviation below the community norm ($M = 100$, $SD = 15$) whereas studies in health samples consistently demonstrate scores at or above the community norm. Consequently, our results may be more generalizable to clinical samples, rather than health, community samples.

STUDY 2: Gray matter correlates of emotional intelligence in incarcerated juvenile male offenders

INTRODUCTION

To our knowledge, no study has attempted to examine whether emotional intelligence is correlated with GMV in adolescents. This study sought to determine whether emotional intelligence is correlated with GMV in somatic marker and limbic regions, namely the insula, vmPFC, ACC, and cerebellum, by examining whether ability emotional intelligence is correlated with GMV in a sample of incarcerated adolescent males using voxel-based morphometry. Furthermore, we assessed whether these relationships were specific to a particular subscale of emotional intelligence (i.e. strategic or experiential).

Based on prior literature, we used the same methods and *a priori* ROIs used in study 1 and hypothesized that, like the adult sample, emotional intelligence would be positively correlated with GMV in limbic regions, including the vmPFC, insula, ACC, and limbic cerebellum.

METHODS

Participants

Study 2 utilized an existing dataset of *n* = 110 incarcerated adolescents recruited from a maximum-security juvenile detention center in New Mexico. This research was also approved by the University of New Mexico Health Sciences Center Institutional Review Board. For this protocol, meetings were scheduled with interested participants and informed consent was obtained. Individuals who are 18 years of age or older provided written informed consent and individuals younger than 18 years of age provided written informed assent in conjunction with parent/guardian written informed consent. Like the adult sample, participants were informed of their right to terminate participation at any point, the lack of direct institutional benefits, and that their participation would not affect their facility status or parole. Participants received remuneration at the hourly labor wage of the facility.

As with study 1, data from only male offenders will be included in this sample given the sex differences in both emotional intelligence (Goldenberg et al., 2006; Schutte et al., 1998) and GMV (Cosgrove et al., 2007; Gur et al., 1999). The same exclusion criteria were applied to the juvenile sample.

Assessments

MSCEIT-YV

In this sample, EI was measured using the MSCEIT-YV-R, a 101-item paper/pencil assessment that is derived from the MSCEIT. The MSCEIT-YV-R is individually administered to each participant and is designed to assess ability to perceive, understand, use and manage emotions to assist thought and action. Similar to the MSCEIT, the MSCEIT-YV-R produces a total score (global EI) and two area scores (experiential and strategic), that are constructed from four facets described above in study 1. (Mayer, Salovey, & Caruso, 2005)

Additional assessments

Additional assessments were administered to assess intelligence quotient (IQ), mental illness, and traumatic brain injury.

General Intelligence:

A two subtest form of the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) was used to collect a full scale IQ estimate for participants under the age of 16. The same two subtest form of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III; Wechsler, 1997) was administered to participants age 16 and older. The two subtests, Vocabulary and Matrix Reasoning, provide a reliable estimate of full scale IQ for both the WISC-IV (Sattler, 1992) and WAIS-III (Ryan, Lopez, & Werth, 1999).

Mental Illness

Presence of mental illness in adolescents was assessed using the Kiddie Schedule for Affective Disorders and Schizophrenia (K-SADS) (Kaufman et al., 1997). Like the adult sample, individuals with a history of psychosis, including Bipolar Disorder and Major Depressive Disorder with psychotic features, a history of Bipolar disorder, and/or any current disorder will be excluded from further analysis.

Traumatic Brain Injury

As with the adult sample, a post-head injury symptoms questionnaire (adapted from King, Crawford, Wenden, Moss, & Wade, 1995) that assesses history, number, and duration of traumatic brain injuries, in addition to related symptoms was administered. Individuals who reported a traumatic brain injury with loss of consciousness of more than 1 h were excluded.

Data Acquisition and Data Analysis

High-resolution T1-weighted structural MRI scans were acquired on the same Mind Research Network Siemens 1.5T Avanto mobile scanner, as was used in the adult sample. Preprocessing and data analyses were conducted in a similar fashion (see study 1).

Whole Brain Analysis

A Monte Carlo simulation conducted using AlphaSim (Ward, 2000) determined that a 536 voxel extent at $p < .001$ uncorrected yielded a corrected threshold of $p < .05$ for Model 1, accounting for spatial correlations between gray matter volumes (GMVs) in neighboring voxel, a 472 voxel extent at $p<.001$ uncorrected yielded a corrected threshold of $p<.05$ for Model 2, and a 519 voxel extent at $p<.001$ uncorrected yielded a corrected threshold of $p<.05$ for Model 3.

ROI Analysis

ROI analysis was conducted using the same *a priori* ROIs identified in study 1. For each region, a small volume correction (SVC) was applied to the area within each mask; we report the false discovery rate (FDR) correction.

RESULTS

Descriptive Statistics

Participants ranged in age from 15 to 19 (*M = 17.62*, *SD = 1.09)* at the time of scanning. Ethnically, participants were predominately Hispanic/Latino (78.2%). 10% of the sample identified as Non-Hispanic White, 2.7% as Non-Hispanic Black/African

American, 5.5% as Non-Hispanic American Indian/Alaskan Native, and 2.7% as more than one racial category. See Figure 6 for complete racial and ethnic breakdown. Similarly to our adult sample, there was no significant racial or ethnic group differences in total EI scores, thus neither race nor ethnicity were included as covariates in our models. IQ ranged from 71-134 (*M=92.33, SD = 10.625).* See Table 5 for descriptive statistics of sample.

MSCEIT - YV

MSCEIT - YV scores in this sample ranged from 65 – 126 *(M=98.54, SD = 13.07).* Experiential EI scores ranged from 63 – 128 *(M=97.18, SD = 12.786)* and strategic EI scores ranged from 64 – 124 *(M=99.41, SD = 13.00).*

Bivariate Correlations

Table 6 shows the bivariate correlations for our variables of interest including MSCEIT total score, experiential EI, strategic EI, Age, IA, and total brain volume. Unexpectedly, MSCEIT-YV total score was not significantly correlated with age (*r=.116, p=.228*), though we expect that this could be due to the restricted age range used in this study. As expected, IQ was significantly correlated with MCEIT-YV total scores (*r=.429, p<.001)*. Experiential (*r=.226, p<.001*) and strategic (*r=.459, p<.001*) subscale scores were significantly correlated with IQ, but neither strategic subscale score (*r=.131, p=.172)* nor experiential subscale score (*r=.045, p=.639*) was significantly correlated with age.

EI Regression Models

Model 1

Based on the cluster extent threshold (536 voxels), GMV analyses across the whole brain produced one large cluster that spanned the precuneus and posterior cingulate cortex that was negatively associated with MSCEIT-YV total scores (Figure 7a, Table 7).

In our ROI analyses, unlike the adult sample, we found no significant associations between MSCEIT total score and GMV that survived small volume correction.

Model 2

The whole brain GMV analysis showed no association with MSCEIT-YV experiential subscale score.

Analyses in our *a priori* ROIs using SVC found no significant correlations between MSCEIT-YV experiential subscale score and GMV in any *a priori* region of interest.

Model 3

In our exploratory analyses, based on the cluster extent threshold (519 voxels) GMV analyses across the whole brain produced two clusters that were significantly negatively associated with MSCEIT-YV strategic subscale score (Figure 7b and Table 7). Additionally, the first cluster spanned the precuneus and posterior cingulate cortex, and the second cluster spanned the precuneus, superior parietal lobule, and postcentral gyrus. Analyses in our *a priori* ROIs using SVC found no significant correlations between MSCEIT-YV experiential subscale score and GMV in any *a priori* region of interest.

DISCUSSION

This is the first study, to our knowledge, to examine the relationship between ability EI and gray matter in adolescents. Contrary to our hypotheses and the pattern we see in adults, cluster extent analysis (using AlphaSim) across the whole-brain indicated that ability emotional intelligence was negatively associated with GMV in limbic regions including the precuneus and PCC. Additionally, though we did not find any evidence of GMV being associated with the experiential factor of EI, we found that strategic EI is negatively associated with GMV in the precuneus, PCC, and cuneus.

In contrast, we did not see any evidence of a relationship between total EI, experiential EI, nor strategic EI with GMV in the vmPFC, insula, ACC, or limbic cerebellum in our SVC ROI analyses.

The somatic marker hypothesis posits that representations of primary inducers – innately pleasurable or aversive unconditioned stimuli or conditioned stimuli that are present in the immediate environment and automatically elicit a somatic response – can either remain covert or reach the parietal cortices and posterior cingulate cortices and be perceived. Thus, the PCC is implicated in emotional processing and emotion perception (Damasio et al., 2000; Maddock, 1999; Maddock, Garrett, & Buonocore, 2003). The results from study 2, which implicate the PCC in EI – specifically, strategic EI – further support the role of the PCC in emotional processes. Another region we found to be associated with EI, the precuneus has also been implicated in emotion processing. In particular, the precuneus is related to self-processing in many domains (Cavanna & Trimble, 2006a) including processing emotions in oneself and others (Ochsner et al., 2004) which is a key component of strategic EI.

These results unexpectedly demonstrate a negative, as opposed to positive correlation with GMV. Though the cause of this phenomenon is unclear, one proposed hypothesis suggests that there may be a relationship between reduced GMV and superior cognitive ability in adolescence and early adulthood. Because emotional intelligence is expected to steadily increase with age while gray matter decreases steadily over the course of adolescence due to neuronal pruning, it is possible that reduced GMV in adolescence is indicative of brain maturation; consequently, individuals with reduced GMV exhibit higher emotional intelligence as a result of this maturation.

Interestingly, the relationship between GMV and EI in the adolescents this study differed in location and direction from the relationship identified in adults in study 1. One possible explanation for this is that age moderates the relationship between EI and GMV. Study 3 will attempt to test this hypothesis.

STUDY 3: Age moderates the relationship between emotional intelligence and gray matter in incarcerated male offenders

INTRODUCTION

One explanation for the differing relationships between EI and gray matter between our adult and juvenile samples, could be a result of an interaction between EI and age. That is, it is possible that the relationship between EI and GMV is moderated by age.

For the purposes of this study, we are using a linear modeling framework to test our hypothesis that the relationship between EI and limbic gray matter, specifically in the precuneus, PCC, ACC, and limbic cerebellum, differs as a function of age. Though there is some evidence in the literature for non-linear effects of age on GMV, prior studies have showed inconsistent findings regarding whether this non-linear pattern can be seen in all brain regions (Abe et al., 2008; Ge et al., 2002; Giedd et al., 1999; Giorgio et al., 2010; Good et al., 2001; Grieve, Clark, Williams, Peduto, & Gordon, 2005; Sowell et al., 2002; Terribilli et al., 2011). In fact, some studies have found that in regions such as the cerebellum, a linear model was the best fit for the data and modeling nonlinearity resulted in no significant improvement of model fit (Good et al., 2001), and regions such as the anterior cingulate show a more distinct, linear pattern of decline than other regions. Despite mixed evidence regarding nonlinearity of GMV decline in the precuneus and posterior cingulate (Abe et al., 2008; Sowell et al., 2002; Storsve et al., 2014; Terribilli et al., 2011) we felt that a linear approach was justified for the purposes of this study.

METHODS

Participants

This study will utilize a sample of the same 247 incarcerated adults recruited from medium and maximum security correctional facilities in New Mexico used in study 1. The same exclusionary criteria were used to determine eligibility.

Assessments

The same battery of assessments measuring EI, IQ, mental illness, and traumatic brain injury administered in studies 1 was used for analyses in this study.

Data Analysis

First and foremost, we conducted a simple linear regression analysis to determine whether the negative relationship between age and GMV and density seen in previous literature is replicated in this sample. Given results in prior literature, we expected a negative linear relationship between age and GMV (Sowell et al., 2002).

To assess whether the relationship between EI and gray matter varies continuously as a function of age, we conducted a moderation analysis to determine whether there is a significant interaction between age and EI that predicts GMV. This method allows us to avoid arbitrary, categorical age cut-offs and assess whether the relationship between EI and gray matter varies continuously as age increases.

Whole-Brain Analysis

To test for distributed gray matter effects, we used AlphaSim (Ward, 2000) to estimate the cluster size necessary to correspond to a desired statistical threshold. A Monte Carlo simulation was conducted using AlphaSim (Ward, 2000) which determined that a 10,269 voxel extent at p < .05 uncorrected yielded a corrected threshold of p < .05, accounting for spatial correlations between gray matter volumes (GMVs) in neighboring voxels.

Probing Significant Interactions

For regions that demonstrated a significant interaction, we extracted eigenvariates from the clusters identified by the whole brain analysis. We then used the average values for a 10 mm sphere around each peak voxel to perform a regression analysis and probe the interaction using the PROCESS macro for SPSS (Hayes & Matthes, 2009) to visual the differential effect of emotional intelligence on GMV in each of these regions at different values of the moderator (age).

RESULTS

Main Effect of Age

As expected based on prior literature, we found that GMV decreases throughout the brain as a function of age, except in the hippocampus which shows a positive correlation with age (Figure 8).

Positive interaction between EI and age predicts GMV in the precuneus

Based on the cluster extent threshold (10,269 voxels), one large cluster spanning the precuneus and postcentral gyrus demonstrated a significant positive MSCEIT total by age interaction effect (Figure 9a, Table 8 & 9). Using extracted eigenvariates from the three peak voxels in this cluster, we probed the interaction effect in SPSS using the PROCESS macro. Specifically, for younger individuals (one standard deviation below the mean, 24.30 years) there was a significant negative correlation between MSCEIT total scores and gray matter in the precuneus, but this relationship did not exist for adults of mean age (33.78 years) or older. In fact, in adults aged one standard deviation above the mean (43.26 years) there was a non-significant positive correlation between MSCEIT total scores and gray matter in the precuneus. This pattern held for both extracted precuneus clusters. (Figure 10a & 10c, Table 10) Although, there was a significant difference in the relationship between MSCEIT total scores and GMV in the postcentral gyrus as a function of age, the conditional effect of MSCEIT total scores on GMV was not significant for young, mean aged, or older adults. (Figure 10b, Table 10)

Negative interaction between EI and age predicts GMV in the cerebellum

Additionally, based on the cluster extent threshold, one large cluster in the cerebellum demonstrated a significant negative MSCEIT total by age interaction effect (Figure 9b, Table 11 & 12). Using extracted eigenvariates from the three peak voxels in this cluster, we probed the interaction effect in SPSS using the PROCESS macro. Specifically, for younger individuals (one standard deviation below the mean, 24.30 years) there was a significant positive correlation between MSCEIT total scores and gray matter in the cerebellum. This relationship did not exist for adults of mean age (33.78 years); however, in adults aged one standard deviation above the mean (43.26 years) there was a significant negative correlation between MSCEIT total scores and gray matter in the cerebellum. (Figure 10d, Table 12). In the vermis, for younger individuals there was significant positive correlation between MSCEIT total scores and GMV, but this relationship was not significant in mean aged or older adults (Figure 10e, Table 12)

Lastly, in the posterior cerebellum, for younger individuals there was a non-significant positive correlation between MSCEIT total scores and GMV, no relationship in mean aged adults, and a non-significant negative correlation between MSCEIT total scores and GMV. (Figure 10f, Table 12)

DISCUSSION

As expected given the contrasting results from study 1 and study 2, we found that age moderates the relationship between EI and GMV, such that younger individuals demonstrated significant negative correlations between EI and precuneus GMV, a relationship does not exist in older adults. Further, older individuals demonstrated positive correlations between EI and cerebellar GMV, while younger individuals either showed no relationship or a negative correlation between EI and cerebellar GMV.

FINAL DISCUSSION

Deficits in emotional intelligence are associated with many negative outcomes including certain forms of psychopathology (e.g. anxiety, substance use, and psychopathy), as well as aggression and interpersonal difficulties. Increased EI, on the other hand, can serve as a protective factor and reduce risk for suicide and trauma-related disorders, as well as both internalizing and externalizing problems. It can also be targeted in treatment and potentially result in improved outcomes.

Prior literature in healthy adults and adolescents suggests that trait EI is associated with GMV and GMC in limbic regions implicated in emotion processing and emotion regulation. These regions include the vmPFC, insula, ACC, and amygdala, in addition to other distributed frontal and temporal regions, as well as the precuneus/cuneus and cerebellum.

Because incarcerated offenders are at increased risk of negative outcomes associated with reduced emotional intelligence, the current study aimed to investigate the relationship between ability EI and GMV in a sample of incarcerated adolescents and adults in order to enhance our knowledge about the construct of emotional intelligence in this population. To accomplish this, we conducted three studies: 1) to assess the relationship between EI and GMV in adult offenders, 2) to assess the relationship between EI and GMV in adolescent offenders, and 3) to determine whether age moderated the relationship between EI and GMV.

In study 1, in both whole-brain, cluster extent threshold analyses and SVC ROI analyses, we found that MSCEIT total scores and strategic subscale scores were positively correlated with GMV in the limbic cerebellum. SVC ROI analyses, but not whole-brain analyses, also showed a significant positive relationship between GMV in the limbic cerebellum and experiential subscale scores. Additionally, SVC ROI analyses found that strategic subscale score was also associated with GMV in the left ACC. Both the cerebellum (Anand, Malhotra, Singh, & Dua, 1959; Sacchetti, Scelfo, & Strata, 2009; Schutter & Honk, 2005; Turner et al., 2007) and ACC (Bush, Luu, & Posner, 2000; Etkin et al., 2011) have been linked to emotional processing across clinical and nonclinical populations and have been identified in prior studies assessing neural correlates of EI. This study adds to that body of literature by providing additional evidence implicating these regions in emotional processing generally, and emotional intelligence in particular.

In study 2, we found in whole-brain, cluster extent threshold analyses that MSCEIT-YV total scores and strategic subscale scores were negatively correlated with GMV in the precuneus and PCC. The PCC is part of the limbic circuitry that has long been implicated in emotion processes (Bush et al., 2000; Johnson et al., 2006; Maddock et al., 2003), and the precuneus, while primarily being involved in self-processing generally, has also been linked to emotion processing (Cavanna & Trimble, 2006b). Both regions have also been associated with trait EI in prior work. Thus, this study provides evidence further implicating these regions in perception, recognition, and processing of emotions in oneself and others, in addition to demonstrating a relationship between these regions and ability EI.

Due to the differing relationships between EI and GMV between our adolescent and adult samples, study 3 sought to determine whether age moderates the relationship between EI and GMV. Mirroring studies 1 and 2, we found that in younger individuals there is a negative correlation between EI and GMV in the precuneus that does not exist in older individuals, while a positive correlation between EI and GMV in the cerebellum was found in older individuals that does not exist in younger individuals.

Taken together, the findings from studies 1, 2, and 3 provide support for the hypothesis that EI is significantly associated with GMV in limbic regions, specifically the precuneus, PCC, ACC, and limbic cerebellum; however, this relationship is significantly moderated by age such that younger individuals show different – and sometimes opposing – relationships between EI and GMV from older adults in these regions.

The identification of neural correlates of emotional intelligence across diverse samples and methodologies not only strengthens our understanding of the construct of emotional intelligence, but these studies, in particular, contribute to our understanding of emotional intelligence over the lifespan in incarcerated individuals.

LIMITATIONS, IMPLICATIONS, & FUTURE DIRECTIONS

Several limitations from the three studies performed should be noted. First, arbitrary age cut-offs distinguished the adolescent sample from the adult sample. Some would even argue that those in the 18-25 age range of our adult sample should be included in the adolescent sample since their brains have not finished developing. Importantly, though, prior studies suggest that gray matter in the frontal and parietal lobes peak around age 12, temporal lobe gray matter peaks around age 16, and gray matter in the occipital lobe may continue to increase to age 20 before beginning to decline through adolescence and adulthood, while primarily white matter continues to develop throughout adolescence and young adulthood (Ge et al., 2002; Giedd et al., 1999; Gur et al., 1999; Sowell et al., 2002). Thus, gray matter in our regions of interest may be finished developing before age 18, providing support for their inclusion in an adult sample. Another age-related limitation, though, is that our adolescent sample only capture late adolescence (15-19) and has a relatively limited age range. Additionally, in an incarcerated sample, it is possible that age could be capturing more variance than just time since birth. Specifically, individuals who are older and in prison are often incarcerated for more severe crimes and have spent more time in prison. Thus, variance related to age, could be attributable to factors like severity of criminal behavior and time spent in prison, rather than biological age.

Next, though our adult sample exhibited a range of MSCEIT scores comparable to prior work, the mean MSCEIT score in this sample was nearly one standard deviation lower than the community norm. Therefore, while our results may generalize to clinical samples with reduced EI, they may not generalize more broadly.

Third, study 3, which measured the moderating effect of age on the relationship between EI and GMV was limited to our adult sample in order to avoid comparing adolescents with MSCEIT-YV scores to adults with MSCEIT (adult version) scores. As a result, we are not able to draw definitive conclusions about the differing results between adult and adolescent samples. Future studies should attempt to use a wider age range to fully examine the moderating effect of age on the relationship between EI and GMV.

Lastly, study 3 used a linear modeling framework to assess the moderating effect of age on the relationship between EI and GMV. That is, the methods used here are ad hoc techniques aimed at transforming the data into a linear modeling paradigm, which rely on the researcher rather the data to lead the modeling. As mentioned previously, though, there is literature to suggest non-linear relationship between age and gray matter in certain regions. Future studies may benefit from utilizing more agnostic, data-driven techniques to infer nonlinear relationships within the data.

Despite these limitations, these studies also had many strengths and have important implications. First and foremost, this is the first study, to our knowledge, to assess the relationship between GMV with ability EI in adolescents.

Additionally, this was the first study looking neural correlates of EI in incarcerated individuals. This is especially important because incarcerated individuals are at a higher risk of negative outcomes related to EI. For this reason, future studies should consider examining EI and the associated gray matter correlates as a risk factor for persistent antisocial behavior and recidivism, and potentially work towards developing interventions to target these deficits to prevent future offending.

An important strength of our study is that we have a very diverse sample. While it does not mirror the racial and ethnic breakdown of the United States as a whole, our adult sample appears to demonstrate a similar racial breakdown to New Mexico which has a higher percentage of minority individuals. Our juvenile sample also demonstrates a high proportion of minority individuals. This suggests an increased generalizability of our findings to diverse populations and the possibility for the development of an intervention that could be used in diverse populations, who are disproportionately incarcerated in the United States (Dumont, Allen, Brockmann, Alexander, & Rich, 2013; Mauer, 2011; Rawal, Romansky, Jenuwine, & Lyons, 2004) and experience a number of other mental health disparities (Blanco et al., 2007; Jackson, Knight, & Rafferty, 2010; Wells, Klap, Koike, & Sherbourne, 2001) associated with reduced EI.

FIGURES

Anatomic Masks Used in ROI Analyses

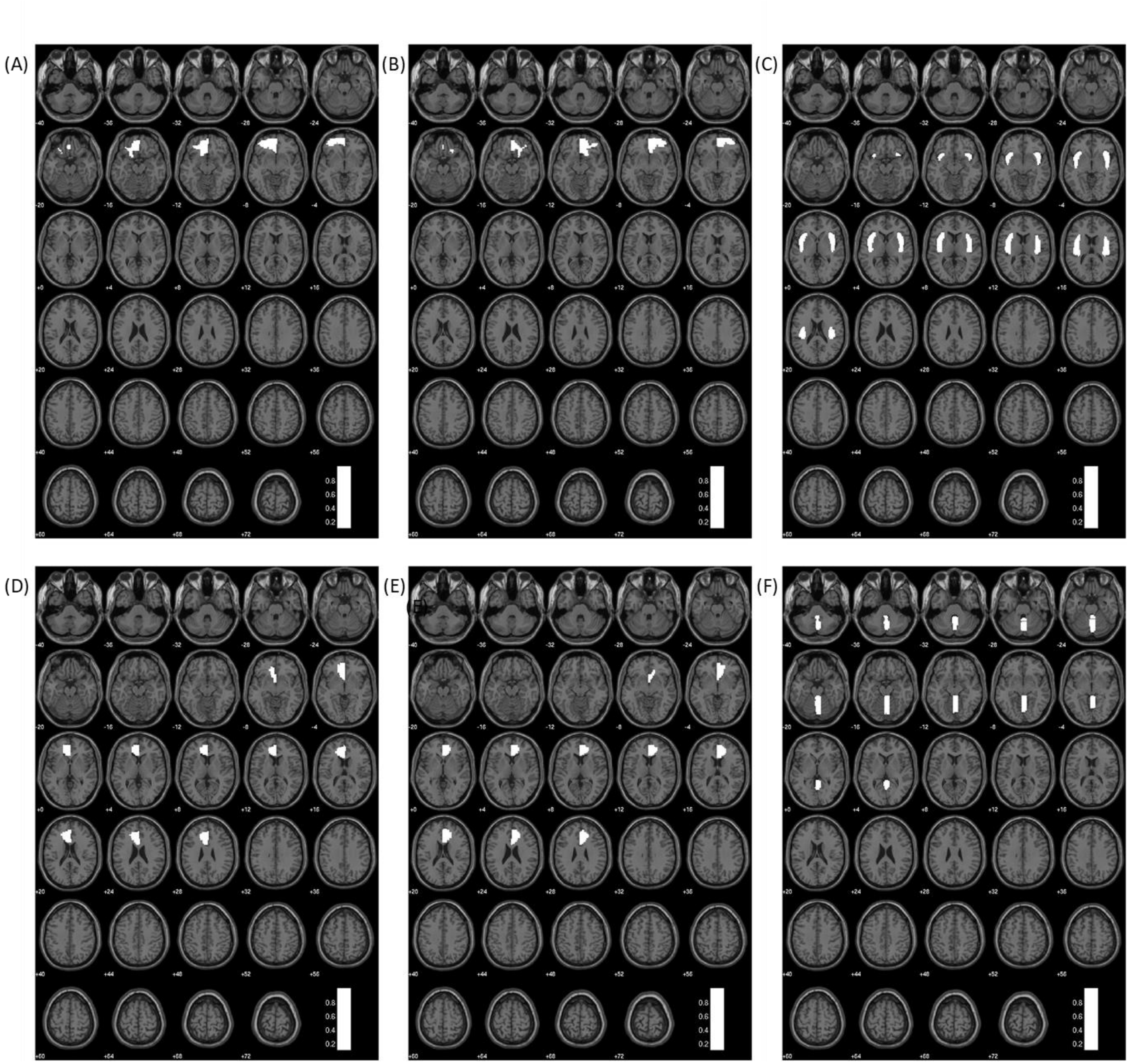

Figure 1. Masks of anatomical ROIs used in SVC ROI analyses. (**A**) Left OFC (**B**) Right OFC **(C)** Left and Right insula **(D)** Left ACC **(E)** Right ACC **(F)** Vermis (cerebellum)

Study 1: Adult Sample Racial and Ethnic Breakdown

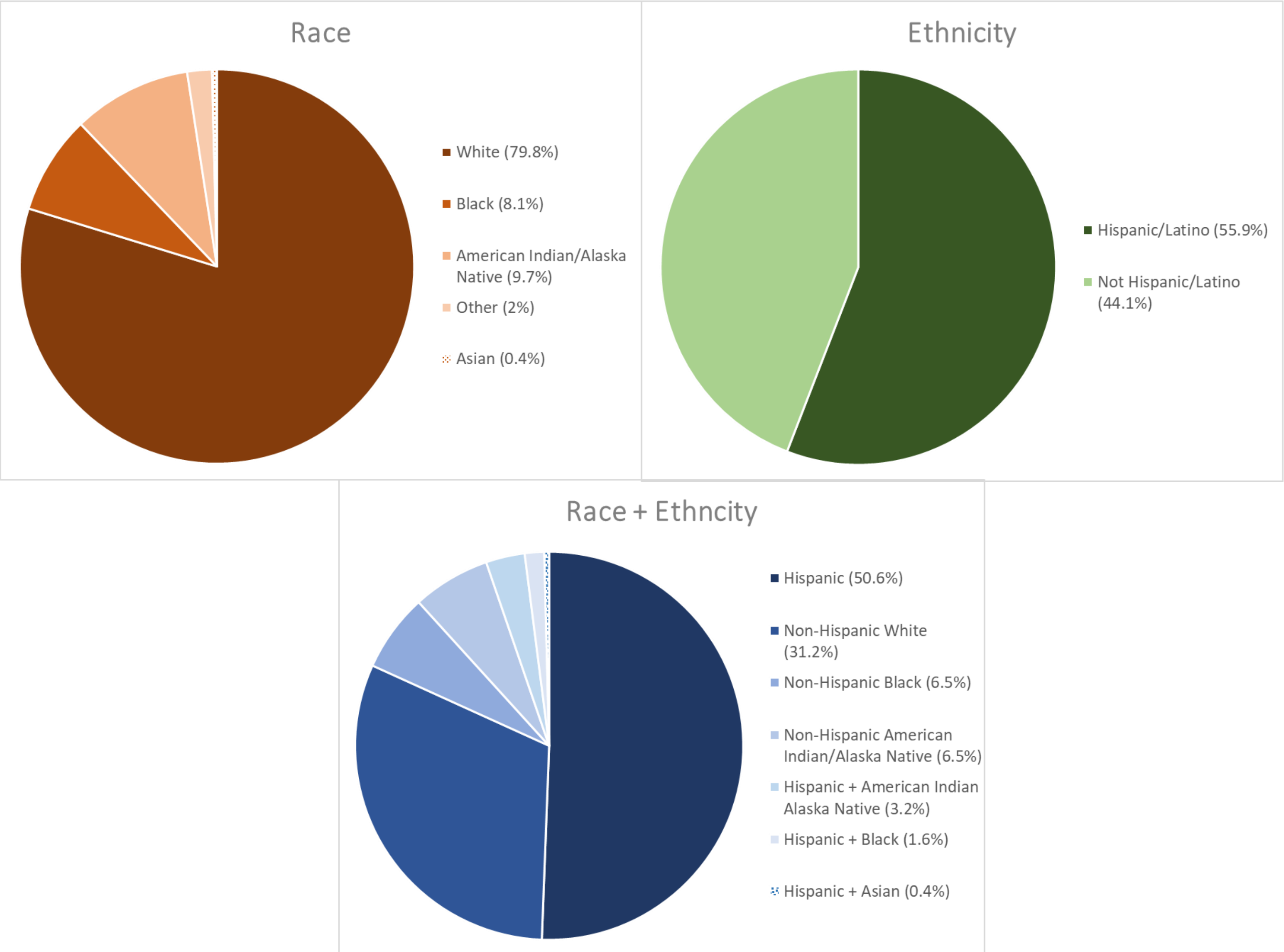

Figure 2. Racial and ethnic background for adult sample used in study 1.

Study 1: MSCEIT Total Positive Correlations with GMV

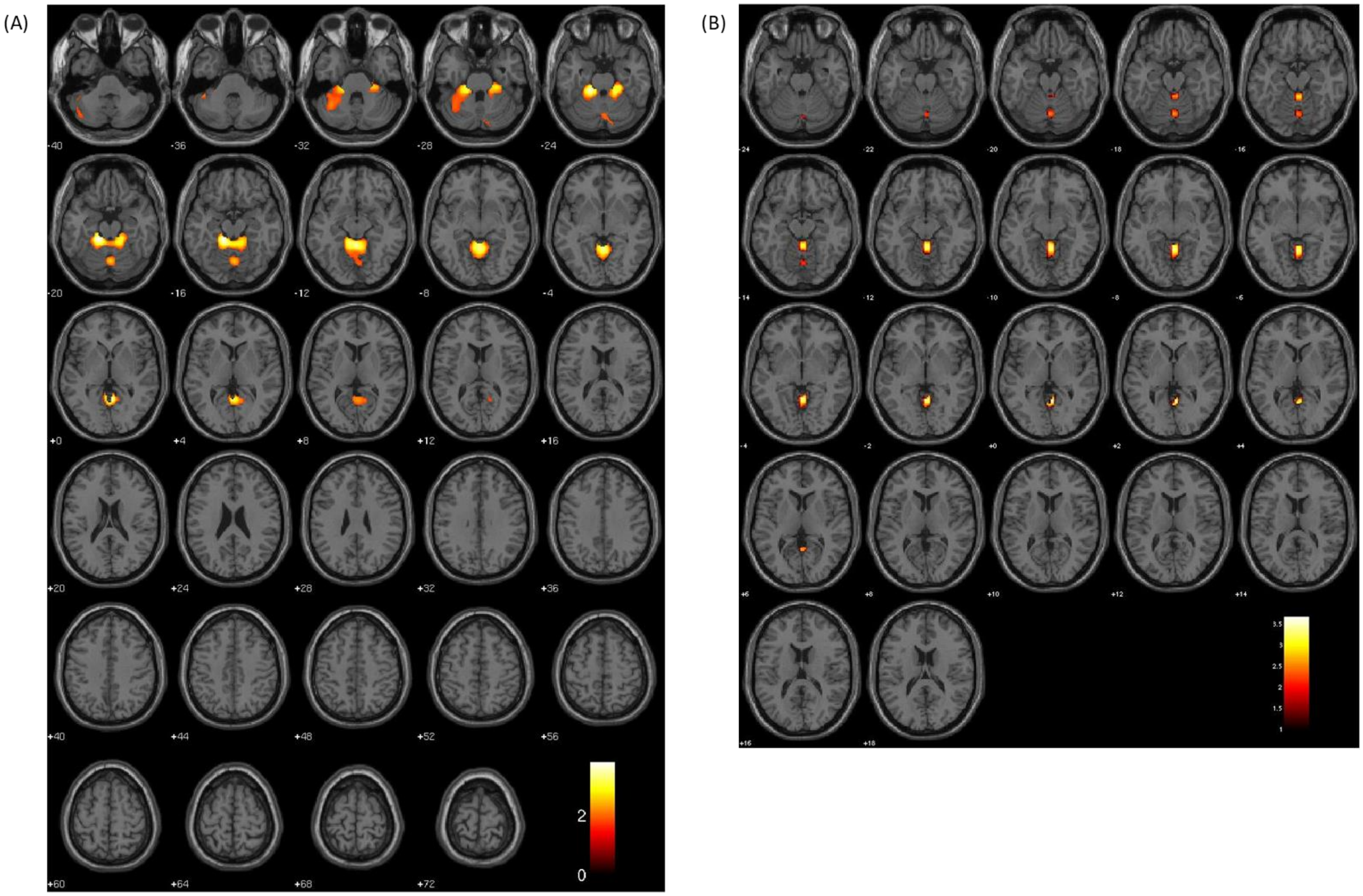

Figure 3. (**A**) Regions associated with MSCEIT total score, using AlphaSim correction. Cluster extent threshold, p<.05, 536 voxels. See table 3 for peak voxel coordinates. Red-yellow scale represents t-values for signal where MSCEIT total score is positively correlated with GMV. (**B**) Regions associated with MSCEIT total score for vermis ROI, SVC corrected. Threshold at $p < .05$, FDR-corrected. Red-yellow scale represents t-values for signal where MSCEIT total score is positively correlated with GMV.

Study 1: MSCEIT Experiential Positive Correlation with Gray Matter Volume

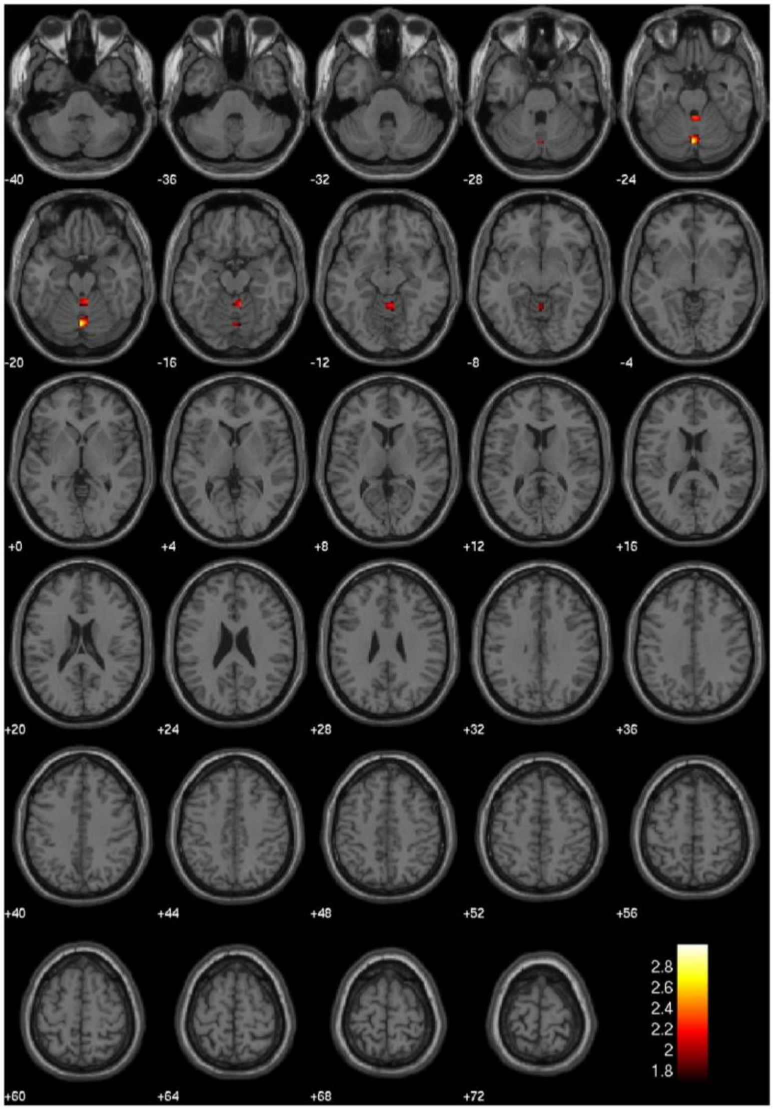

Figure 4. Regions associated with MSCEIT experiential subscale score for vermis ROI, SVC corrected. Threshold at *p* < .05, FDR-corrected. Red-yellow scale represents t-values for signal where MSCEIT experiential subscale score is positively correlated with GMV.

Study 1: MSCEIT Strategic Positive Correlation with Gray Matter Volume

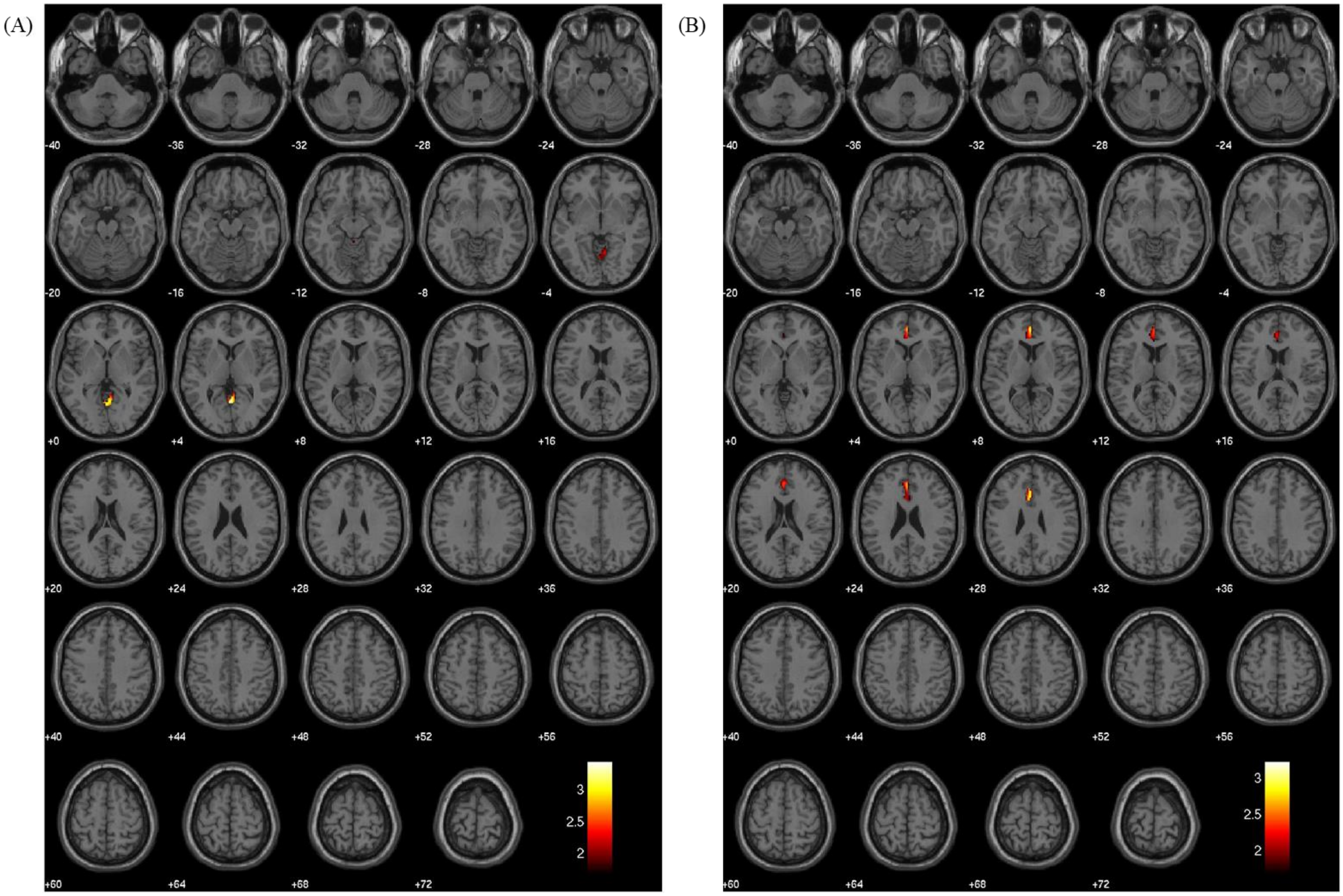

Figure 5. (**A**) Regions associated with MSCEIT strategic subscale score for vermis ROI, SVC corrected. Threshold at $p < .05$, FDR-corrected. Red-yellow scale represents t-values for signal where MSCEIT strategic subscale score is positively correlated with GMV. (**B**) Regions associated with MSCEIT strategic subscale score for left ACC ROI, SVC corrected. Threshold at $p < .05$, FDR-corrected. Red-yellow scale represents t-values for signal where MSCEIT strategic subscale score is positively correlated with GMV.

Study 2: Juvenile Sample Racial and Ethnic Breakdown

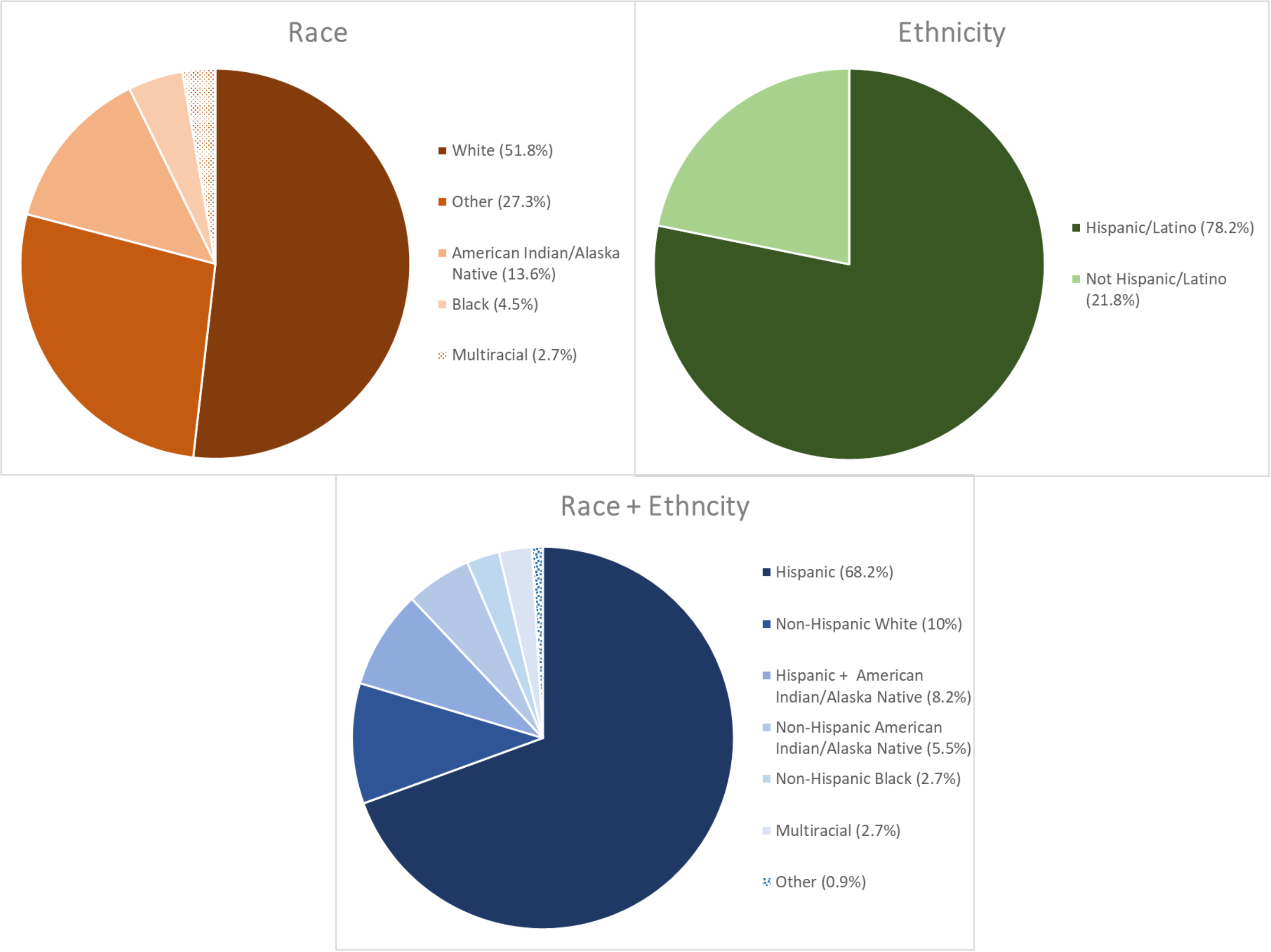

Figure 6. Racial and ethnic background for juvenile sample used in study 2.

Study 2: MSCEIT-YV Total and Strategic Negative Correlation with GMV

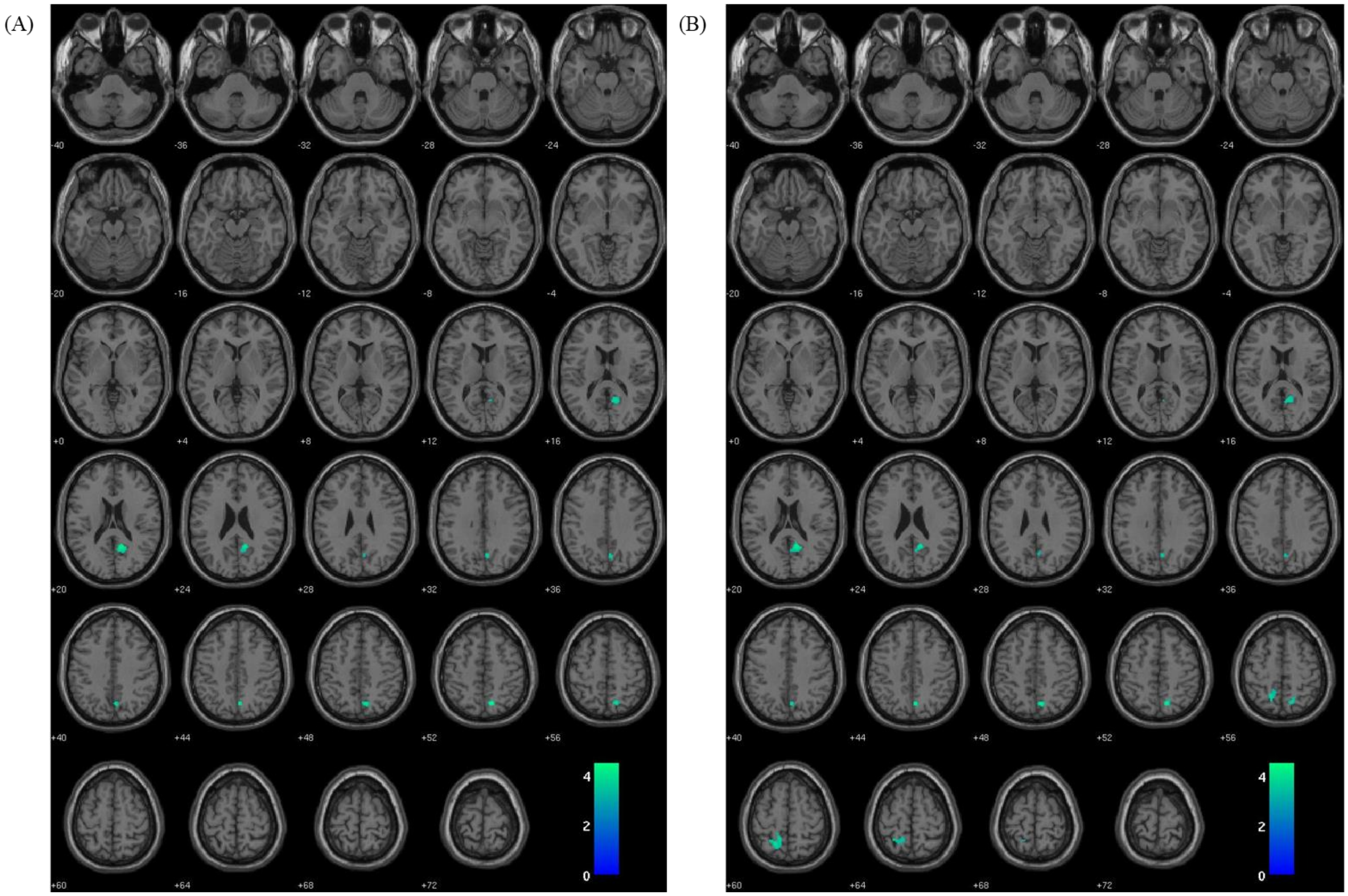

Figure 7. (**A**) Regions associated with MSCEIT-YV total score, using AlphaSim correction. Cluster extent threshold, p <. 001, 536 voxels. See table 8 for peak voxel coordinates. Blue-green scale represents t-values for signal where MSCEIT-YV total score is negatively correlated with GMV. (**B**) Regions associated with MSCEIT-YV strategic subscale score, using AlphaSim correction. Cluster extent threshold, p < .001, 519 voxels. See table 8 for peak voxel coordinates. Blue-green scale represents t-values for signal where MSCEIT-YV strategic subscale score is positively correlated with GMV.

Study 3: Gray Matter Volume Effect on Age

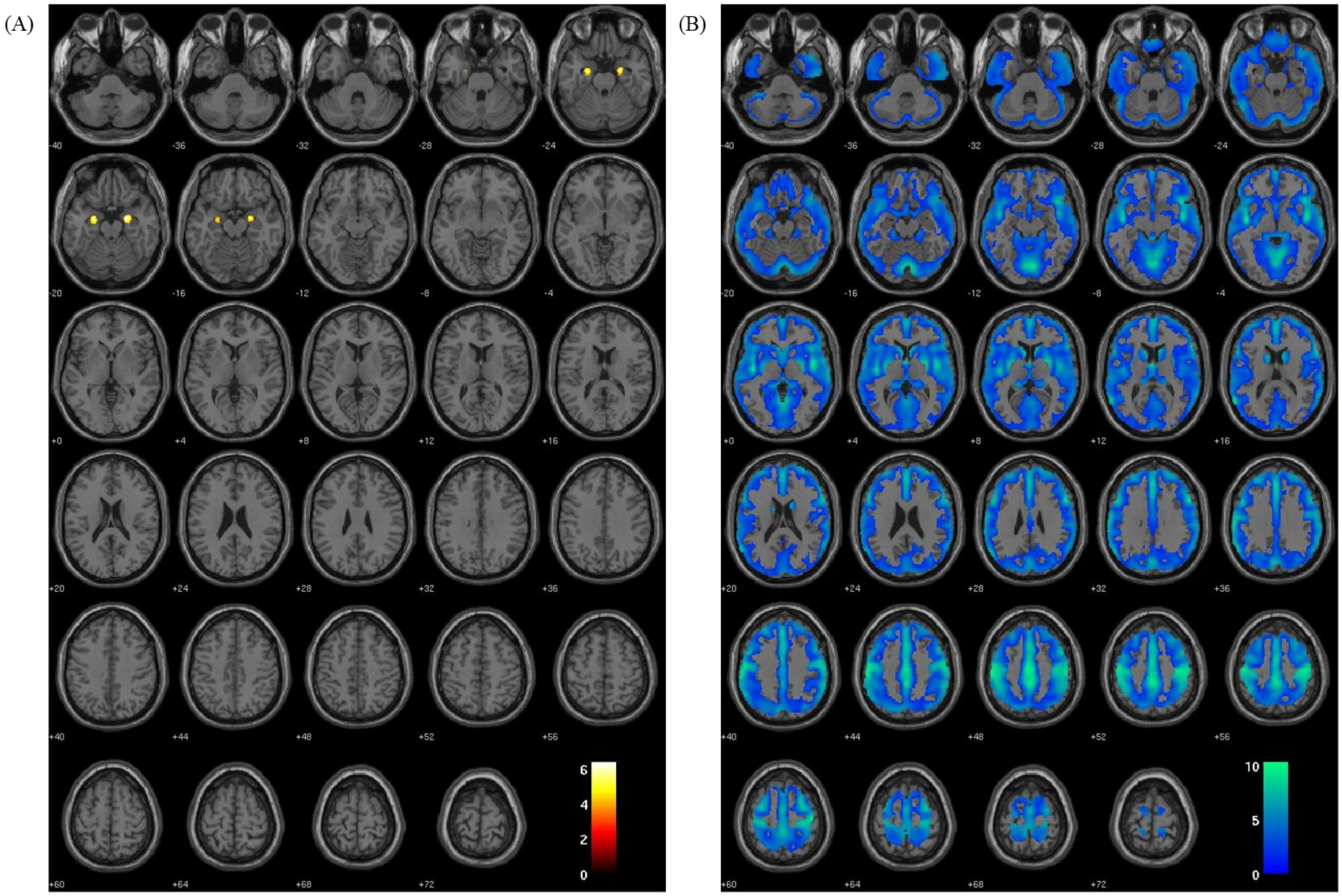

Figure 8. (**A**) Regions in which GMV is positively associated with age, using whole-brain FDR correction $p < .05$. Results suggest GMV in the bilateral hippocampus and cerebellum is positively associated with age. (**B**) Regions in which GMV is negatively associated with age, using whole-brain FDR correction $p < .05$. Results suggest that GMV exhibits global reductions as a function of increasing age.

Study 3: MSCEIT x Age Interaction effects

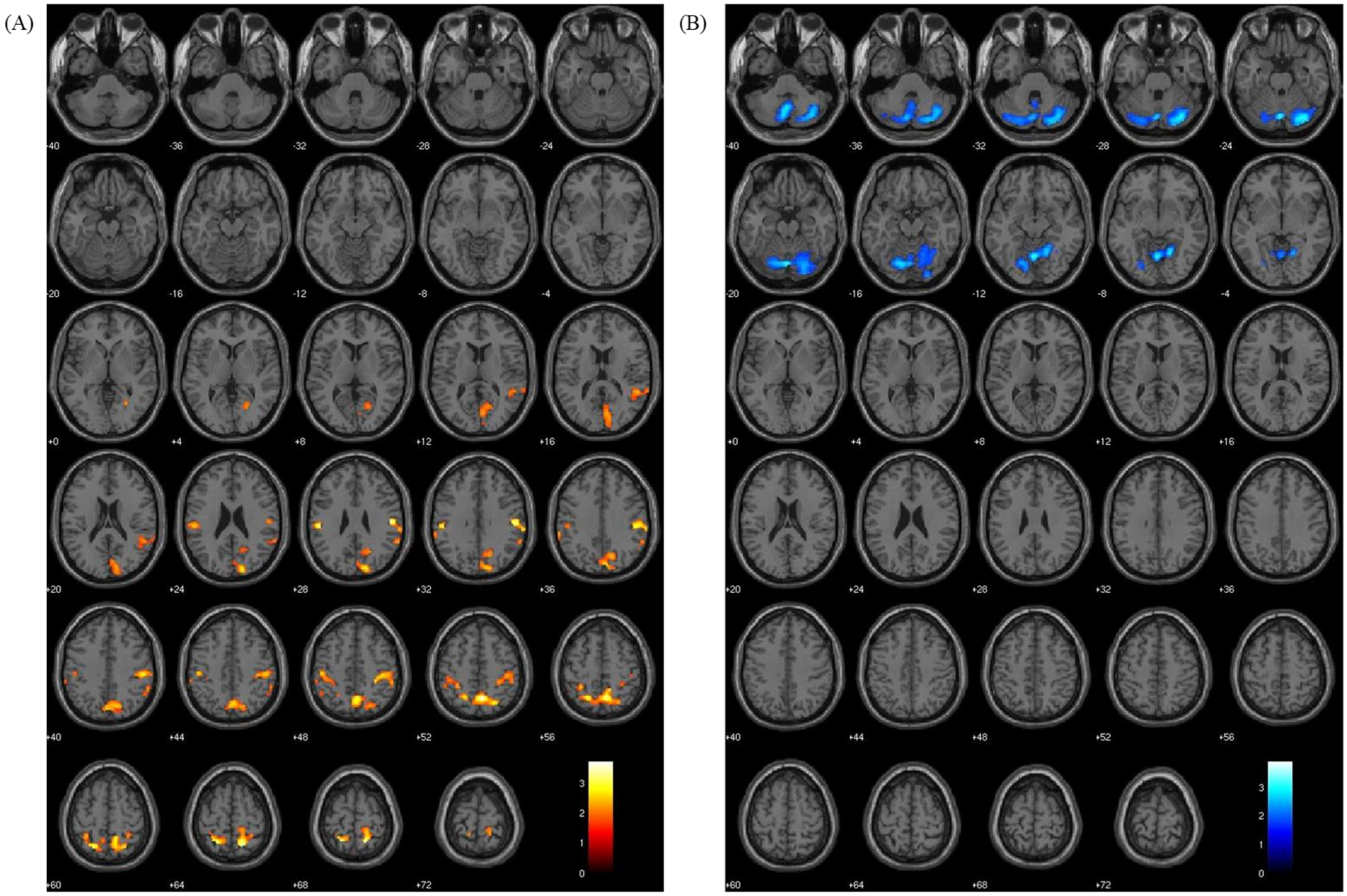

Figure 9. (**A**) Regions that demonstrate a positive MSCEIT total score by age interaction effect, using AlphaSim correction. Cluster extent threshold, p<.05, 10,269 voxels. See table 9 for peak voxel coordinates. Red-yellow scale represents t-values for signal where MSCEIT total score by age interaction is positively correlated with GMV. (**B**) Regions that demonstrate a negative MSCEIT total score by age interaction effect, using AlphaSim correction. Cluster extent threshold, p<.05, 10,269 voxels. See table 9 for peak voxel coordinates. Blue-green scale represents t-values for signal where MSCEIT total score by age interaction is negatively correlated with GMV.

Study 3: Simple Slopes Graphs for MSCEIT x Age Interaction

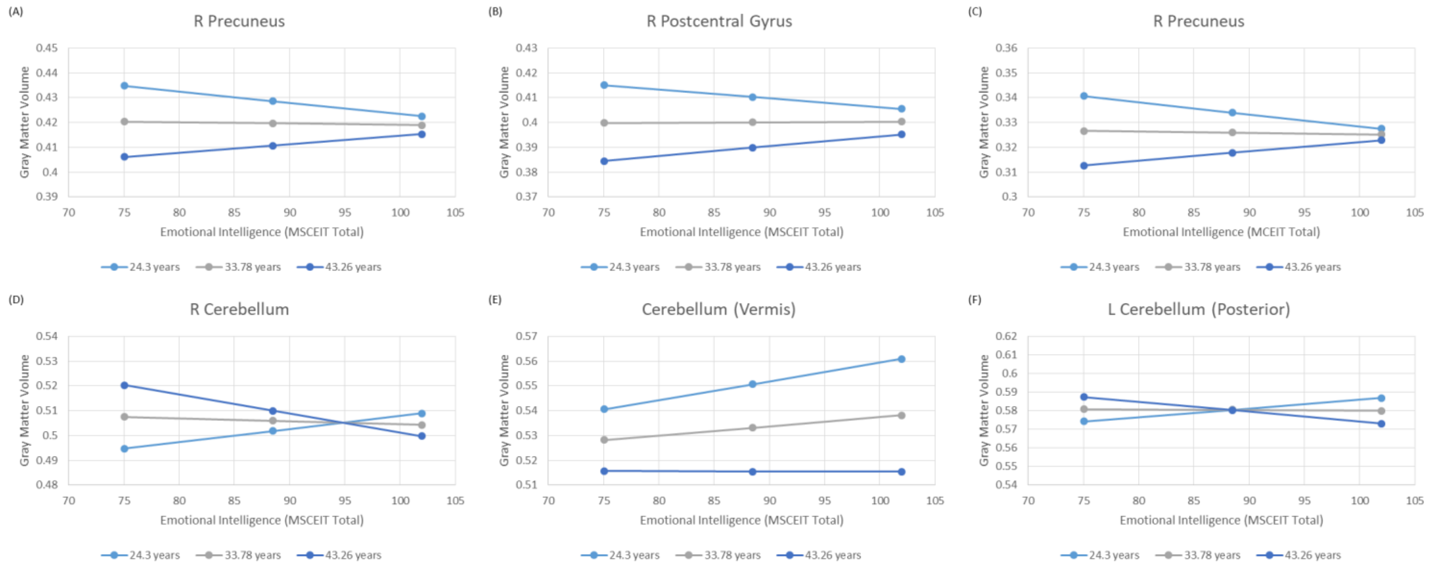

Figure 10. Simple slopes graphs showing conditional effects of emotional intelligence on GMV at levels of the moderator (age). (**A**) Positive interaction effect in the right precuneus (peak voxel: 6 60 52). 24.3 years, r = -.0005, *p* = .025; 33.78 years, r = -.0001, *p* = .7172; 43.26 years, r = .0003, *p* = .1237. (**B**) Positive interaction effect in the right postcentral gyrus (peak voxel: 55 -19 30). 24.3 years, r = -.0004, *p* = .1000; 33.78 years, r = .0000, *p* = .9026; 43.26 years, r = .0004, *p* = .1045. (**C**) Positive interaction effect in the right precuneus (peak voxel: 15 55 66). 24.3 years, r = -.0005, *p* = .0188; 33.78 years, r = -.0001, *p* = .7378; 43.26 years, r = .0004, *p* = .1080. (**D**) Negative interaction effect in the right cerebellum (peak voxel: 33 -56 -56). 24.3 years, r = -.0005, *p* = .0383; 33.78 years, r = -.0001, *p* = .5606; 43.26 years, r = -.0008, *p* = .0083. (**E**) Negative interaction effect in the cerebellar vermis (peak voxel: 0 -63 -11). 24.3 years, r = .0008, *p* = .0031; 33.78 years, r = .0004, *p* = .0687; 43.26 years, r = .0000, *p* = .9625. (**F**) Negative interaction effect in the left posterior cerebellum (peak voxel: -2 -61 -44). 24.3 years, r = .0005, *p* = .1115; 33.78 years, r = .0000, *p* = .8866; 43.26 years, r = -.0005, *p* = .1085.

TABLES

Table 1

Study 1: Descriptive Statistics for Variables (n = 247)

Column Head	Minimum	Maximum	Mean	Standard Deviation
Age	18	60	33.78	9.482
IQ	72	137	96.77	13.730
MSCEIT Total	58	114	88.54	13.44
MSCEIT Strategic	46	113	84.66	10.40
MSCEIT Experiential	56	131	97.47	15.55

Note: Assessments: Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale – Third Version (WAIS-III; Wechsler, 1997). Emotional Intelligence (EI) Total, Strategic, and Experiential scores were calculated from the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer et al., 2003)

Table 2

Study 1: Correlations among MSCEIT Variables and Covariates (n = 247)

	GM+WM	Age	IQ	MSCEIT Total	MSCEIT Strategic
Total Brain Volume (GM + WM)	1				
Age	-.310**	1			
IQ	.186*	.119	1		
MSCEIT Total	.078	.125*	.460**	1	
MSCEIT Strategic	.085	.268**	.523**	.876**	1
MSCEIT Experiential	.030	-.046	.281**	.871**	.547**

Note: Assessments: Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale – Third Version (WAIS-III; Wechsler, 1997). Emotional Intelligence (EI) Total, Strategic, and Experiential scores were calculated from the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer et al., 2003)

** p < .001, * p ≤ .05

Table 3

Study 1: Whole-Brain MRI Analysis Results for MSCEIT Total Score – Gray Matter Volume (n= 247)

		Region	x	y	z	p value	t-value
Model 1	MSCEIT Total Score	Cerebellum (Vermis)	-14	-37	-18	<.001	3.73
			3	-54	1	<.001	3.66
			2	-46	-11	<.001	3.40

Note: Model 1 - Investigating the relationship between total EI and GMV using cluster extent threshold, 396 voxels. p<.001, unc, AlphaSim corrected to p<.05. Coordinates are given in MNI space.

Table 4

Study 1: Small Volume Corrected Results for MSCEIT Total and Subscale Scores – Gray Matter Volume (n = 247)

		Region	x	y	z	p value	t-value
Model 1	MSCEIT Total Score	Cerebellum (Vermis)	3	-54	1	0.017	3.66
			2	-46	-11	0.017	3.40
			-2	-54	3	0.017	3.23
			3	-69	-18	0.034	2.61
Model 2	MSCEIT Experiential Score	Cerebellum (Vermis)	2	-49	-9	0.050	3.14
			2	-69	021	0.050	3.05
			-4	-42	-21	0.053	2.55
Model 3	MSCEIT Strategic Score	Left ACC	-3	20	30	0.044	3.26
			-2	36	6	0.044	3.17
			0	9	27	0.046	2.60
		Cerebellum (Vermis)	3	-55	3	0.015	4.07
			-2	-54	3	0.015	3.85
			-2	-42	-11	0.030	2.96

Note: Investigating the relationship between EI and GMV using small volume correction in ROIs defined by anatomical boundaries using the automated anatomical labels (AAL) feature in the WFU PickAtlas toolbox available in SPM. ROIs were generated for the left and right vmPFC, left and right insula, left and right ACC, and vermis. Coordinates are given in MNI space. All *p*'s < .05, and were corrected for False Discovery Rate (FDR).

Table 5

Study 2: Descriptive Statistics for Variables (n = 110)

Column Head	Minimum	Maximum	Mean	Standard Deviation
Age	15	19	17.62	1.092
IQ	71	134	92.33	10.625
MSCEIT-YV Total	65	126	98.54	13.07
MSCEIT-YV Experiential	63	128	97.18	12.786
MSCEIT-YV Strategic	64	124	99.41	13.00

Note: Assessments: Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale – Third Version (WAIS-III; Wechsler, 1997) and Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003). Emotional Intelligence (EI) Total, Strategic, and Experiential scores were calculated from the Mayer-Salovey-Caruso Emotional Intelligence Test – Youth Version (MSCEIT - YV; Mayer, Salovey, & Caruso, 2005)

Table 6

Study 2: Correlations among MSCEIT-YV Variables and Covariates (n = 110)

	GM+WM	Age	IQ	MSCEIT-YV	MSCEIT-YV Strategic
Total Brain Volume (GM + WM)	1				
Age	-.058	1			
IQ	.217*	.107	1		
MSCEIT-YV Total	.156	.116	.429**	1	
MSCEIT-YV Experiential	.111	.045	.226**	.774**	.560**
MSCEIT-YV Strategic	.154	.131	.459**	.958**	1

Note: Assessments: Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale – Third Version (WAIS-III; Wechsler, 1997) and Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003). Emotional Intelligence (EI) Total, Strategic, and Experiential scores were calculated from the Mayer-Salovey-Caruso Emotional Intelligence Test – Youth Version (MSCEIT - YV; Mayer, Salovey, & Caruso, 2005)

** p < .001, * p < .05

Table 7

Study 2: Whole-Brain MRI Analysis Results for MCEIT-YV Total and Subscale Scores - Gray Matter Volume (n = 110)

		Region	x	y	z	p value	t-value
Model 1	MSCEIT-YV Total Score	R Superior Parietal Lobule	12	-66	52	p<.001	4.46
		R Posterior Cingulate	14	-52	21	p<.001	4.29
		R Precuneus	6	-66	43	p<.001	4.09
Model 3	MSCEIT-YV Strategic Score	R Precuneus	9	-67	48	p<.001	4.52
		R Posterior Cingulate	15	-51	22	p<.001	4.42
		R Cuneus	6	-66	33	p<.001	3.60
		L Precuneus	-16	-57	58	p<.001	4.13
		L Superior Parietal Lobule	-24	-51	61	p<.001	3.82
		L Postcentral Gyrus	-12	-48	61	p<.001	3.66

Note: Model 1 - Investigating the relationship between total EI and GMV using cluster extent threshold, 536 voxels. p<.001, unc, AlphaSim corrected to p<.05. Model 3 - Investigating the relationship between strategic EI and GMV using cluster extent threshold, 519 voxels. p<.001, unc, AlphaSim corrected to p<.05. Coordinates are given in MNI space.

Table 8

Study 3: Whole Brain MRI Analysis Results for MSCEIT x Age Interaction – Gray Matter Volume (n = 247)

		Region	x	y	z	p value	t-value
MSCEIT-YV Total Score x Age (Interaction)	Positive	R Precuneus	6	-60	52	< .001	3.72
		R Postcentral Gyrus (B2)	55	-19	30	<.001	3.54
		R Precuneus	15	-55	66	<.001	3.48
	Negative	R Cerebellum	33	-56	-56	<.001	3.90
		Cerebellum (Vermis)	0	-63	-11	<.001	3.39
		L Cerebellum (Posterior)	-2	-61	-44	<.001	3.32

Note: Investigating the relationship between EI and GMV using cluster extent threshold, 10,269 voxels. p<.05, unc, AlphaSim corrected to p<.05. Coordinates are given in MNI space.

Table 9

Study 3: Linear Regression Analysis for MSCEIT x Age Interaction - Positive (n = 247)

Model	Predictors	B	SE B	t	Sig.
Regression 1: R Precuneus (6 60 52)	Age	-.0047	.0013	-3.5847	.0004
	MSCEIT Total	-.0015	.0005	-2.9716	.0033
	IQ	.0002	.0002	1.3603	.1750
	TBV	.0004	.0000	19.3948	<.0001
	MSCEIT Total x Age	.0000	.0000	2.8875	.0042
Regression 2: R Postcentral Gyrus (55 -19 30)	Age	-.006	.0014	-3.2012	.0016
	MSCEIT Total	-.0013	.0005	-2.4091	.0167
	IQ	-.0002	.0002	-.9594	.3383
	TBV	.0003	.0000	13.7937	<.0001
	MSCEIT Total x Age	.0000	.0000	2.4735	.0141
Regression 3: R Precuneus (15 55 66)	Age	-.0049	.0014	-3.5666	.0004
	MSCEIT Total	-.0016	.0005	-3.0405	.0026
	IQ	.0003	.0002	1.7285	.0852
	TBV	.0003	.0000	15.0090	<.0001
	MSCEIT Total x Age	.0000	.0000	2.9659	.0033

Regression 1: $R^2 = .6947$, $R = .8335$, $F(5,241) = 109.6576$
Regression 2: $R^2 = .5507$, $R = .7421$, $F(5,241) = 59.0880$
Regression 3: $R^2 = .5902$, $R = .7683$, $F(5,241) = 69.4212$

Note: Regression analyses for extracted eigenvariates from peak voxels that demonstrated positive interaction effect. Assessments: Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale – Third Version (WAIS-III; Wechsler, 1997) and Wechsler Intelligence Scale for Children – Fourth Edition (Wechsler, 2003). Emotional Intelligence (EI) Total, Strategic, and Experiential scores were calculated from the Mayer-Salovey-Caruso Emotional Intelligence Test – Youth Version (MSCEIT - YV; Mayer, Salovey, & Caruso, 2005) and Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; (Mayer et al., 2003).

Table 10

Study 3: Conditional effect of MSCEIT on Gray Matter Volume at Values of Moderator - Positive

Model	Age	Effect	se	t	Sig.
Regression 1: R Precuneus (6 60 52)	**24.2950**	**-.0005**	**.0002**	**-2.3328**	**.0205**
	33.7773	-.0001	.0002	-.3626	.7172
	43.2596	.0003	.0002	1.5449	.1237
Regression 2: R Postcentral Gyrus (55 -19 30)	24.2950	-.0004	.0002	-1.6512	.1000
	33.7773	.0000	.0002	.1224	.9026
	43.2596	.0004	.0002	1.6296	.1045
Regression 3: R Precuneus (15 55 66)	**24.2950**	**-.0005**	**.0002**	**-2.3662**	**.0188**
	33.7773	-.0001	.0002	-.3351	.7378
	43.2596	.0004	.0002	1.6132	.1080

Note: Significant correlations are **bolded**.

Table 11

Study 3: Linear Regression Analysis for MSCEIT x Age Interaction - Negative (n = 247)

Model	Predictors	B	SE B	t	Sig.
Regression 4: R Cerebellum (33 -56 -56)	Age	-.0065	.0017	3.8287	.0002
	MSCEIT Total	.0022	.0006	3.3848	.0008
	IQ	.0005	.0002	2.3593	.0004
	TBV	.0003	.0000	11.5871	<.0001
	MSCEIT Total x Age	-.0001	.0000	-3.6059	.0191
Regression 5: Cerebellum (Vermis) (0 -63 -11)	Age	.0017	.0017	1.0249	.3064
	MSCEIT Total	.0017	.0006	2.7017	.0074
	IQ	.0000	.0002	.1281	.8982
	TBV	.0003	.0000	13.4707	<.0001
	MSCEIT Total x Age	.0000	.0000	-2.1482	.0327
Regression 6: L Cerebellum (Posterior) (-2 -61 -44)	Age	.0047	.0020	2.3880	.0177
	MSCEIT Total	.0018	.0007	2.3504	.0196
	IQ	.0003	.0002	1.2688	.2057
	TBV	.0003	.0000	11.5285	<.0001
	MSCEIT Total x Age	-.0001	.0000	-2.4206	.0162

Regression 1: $R^2 = .4260$, R = .6527, F (5,241) = 35.7757
Regression 2: $R^2 = .5905$, R = .7684, F (5,241) = 69.5018
Regression 3: $R^2 = .4165$, R = .6453, F (5,241) = 34.3979
Note: Regression analyses for extracted eigenvariates from peak voxels that demonstrated negative interaction effects. Assessments: Intelligence Quotient (IQ) was calculated from the Wechsler Adult Intelligence Scale – Third Version (WAIS-III; Wechsler, 1997). Emotional Intelligence (EI) Total, Strategic, and Experiential scores were calculated from the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer et al., 2003).

Table 12

Study 3: Conditional effect of MSCEIT on Gray Matter Volume at values of moderator - Negative

Model	Age	Effect	se	t	Sig.
Regression 4: R Cerebellum (33 -56 -56))	**24.2950**	**.0005**	**.0002**	**2.0831**	**.0383**
	33.7773	-.0001	.0002	-.5827	.5606
	43.2596	**-.0008**	**.0003**	**-2.6614**	**.0083**
Regression 5: Cerebellum (Vermis) (0 -63 -11)	**24.2950**	**.0008**	**.0003**	**2.9852**	**.0031**
	33.7773	.0004	.0002	1.8288	.0687
	43.2596	.0000	.0003	-.0471	.9625
Regression 6: L Cerebellum (Posterior) (-2 -61 -44)	24.2950	.0005	.0003	1.5975	.1115
	33.7773	.0000	.0002	-.1427	.8866
	43.2596	-.0005	.0003	-1.6109	.1085

Note: Significant correlations are **bolded**.

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