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The Reflection of Self-Esteem on the Brain Structure: A Voxel Based Morphometry Study in Healthy Young Adults

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ABSTRACT

Introduction: Low self-esteem is a known risk factor for mental illnesses. Neuroimaging studies have identified evidence for a functional association between default mode network (DMN) and self-esteem levels. However, it is not clear whether there is a similar association between trait self-esteem and the structures composing DMN. This study aimed to investigate the relationship between the DMN associated brain structures and trait self-esteem.

Methods: We obtained 3T structural magnetic resonance imaging (MRI) data of 75 healthy subjects and detected anatomical regions correlated with their Rosenberg Self-Esteem scores via voxel-based morphometry (VBM).

Results: We found positive associations between self-esteem and regional grey matter volumes in the right temporoparietal junction/inferior parietal lobule (BA 39), cortical midline regions at precuneus/dorsal cingulate cortex (BA 31), rostral and dorsal anterior cingulate cortices (BA 32).

Conclusion: The results of the current study support the fMRI studies suggesting self-esteem levels associated with DMN. Further neuroimaging studies should consider the functional and structural coupling of the default mode network during the execution of the functions related to self-esteem.

Keywords: Default mode network (DMN), DSM-5, structural MRI, temporoparietal junction (TPJ), trait self-esteem, voxel-based morphometry (VBM)

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INTRODUCTION

Self-esteem is a construct described as "a conglomerate measure of one's sense of self-worth based on perceived personal success and achievements, as well as a perception of how much one is valued by others and society in general" (1). In line with self-compassion, self-esteem has begun to refer to the degree of being worthful or significant for the self and others (2). Self-esteem is established by the interaction of biological and environmental factors during childhood and adolescence and it is an important personality trait which enables considerable intraindividual stability throughout life (1,2). The degree of self-esteem is a significant factor in how one perceives and responds to daily hassles and chronic stressors (2). Thus, it is a predictor for mental health and quality of life (3). Low self-esteem levels are associated with negative affects which increase vulnerability to affective disorders like major depression and anxiety disorders (4). It is noteworthy that similar behavioral and biological findings were observed in depressed patients and healthy subjects with low self-esteem (4). On the other hand, high self-esteem is associated with resilience to mental disorders (5). Thus, understanding the neurobiology of self-esteem can help us understand the vulnerability and resiliency to depression and anxiety disorders.

Highlights

- **Self-esteem levels and whole brain gray matter volumes were evaluated with VBM.**
- **Self-esteem was correlated with TPJ/IPL, PCC/Pcu, rostral and dorsal ACC.**
- **Our findings coincide with PCC/Pcu, ACC and rTPJ regions of DMN.**

The neuroimaging studies have provided evidence for underlying neural mechanisms of self-related processes, especially self-esteem. Functional magnetic resonance imaging (fMRI) results demonstrated that the cognitive operations assembling self-esteem were executed by the midline

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cortical areas and areas related to Theory of Mind (ToM, understanding others' minds) (6). Yang et al. (2) demonstrated that the levels of trait self-esteem were negatively associated with the neural activity in the dorsal anterior cingulate activity (dACC) in response to evaluating self-relevant information. The same group later showed that trait self-esteem was associated with the orbitofrontal activity while evaluating one's positive traits but with the medial prefrontal and posterior cingulate cortices during the assessment of positive social feedback (7). They also suggested that trait self-esteem modulates the degree of affective processes in the orbitofrontal cortex during self-reflection and cognitive processes in the medial prefrontal cortex during the evaluation of social feedback. On the other hand, Eisenberger et al. (6) found that state self-esteem was negatively associated with the neural activity in the anterior insula, dACC, and dorsomedial prefrontal cortex (dmPFC) during social feedbacks about the self. In the same study, subjects who had decreased state self-esteem during negative social feedback had higher medial prefrontal cortex activity than those with more consistent state self-esteem. An fMRI study using the amplitude of low-frequency fluctuations (ALFFs) demonstrated that the trait self-esteem has a positive correlation with the left ventromedial prefrontal cortex (vmPFC) and a negative correlation with the cuneus/lingual gyrus (8). In the same study, the seed-based resting-state functional connectivity (RSFC) analysis showed higher functional connectivity between vmPFC and the bilateral hippocampus, associated with higher self-esteem.

A common finding of all the functional studies is that midline cortical regions play a significant role in the cognitive processes related to self-esteem. Anterior and posterior cortical midline regions are the parts of the default mode network (DMN) which involves a variety of internally-directed mental representations linked to self-esteem like self-reflection, autobiographical memory, future event simulation, mind wondering, conceptual processing (9). Indeed, one study reported a direct positive correlation between Rosenberg Self-esteem scores and cerebral blood flows in the DMN regions of PCC/PCu, medial prefrontal cortex (mPFC), and inferior parietal lobule (IPL) (10). Thus, functional studies suggest that DMN is the primary network during the construction of self-esteem.

Structure-function relationships are a fundamental principle of many naturally occurring systems, including the central nervous system of humans. The function of the neural system is analogously shaped by the structure and arrangement of neurons (3). Therefore, the structural integrality of the brain might determine the function. This approach was tested for many cognitive processes, including self-related concepts. Some studies provided evidence that increased self-esteem levels are associated with larger hippocampal volumes (3,7,11). On the other hand, to our knowledge, there is only one whole-brain VBM study which compiled two independent study samples and found a positive association between trait self-esteem and the volumes of anterior cingulate, lateral prefrontal cortices, right hippocampus, hypothalamus, and right temporoparietal junction (TPJ) (3). They proposed that trait self-esteem is associated with the brain structures responsible for emotion regulation and the theory of mind. However, the small sample size of this study limited the validity of the findings (3) (see Yarkoni (2009) (12) in order to obtain details regarding this subject).

Although the functional correlates of self-esteem are well-studied, we have limited information on structural correlates of it. In the present study, we aim to extend the current knowledge of brain structures related to the trait self-esteem. Based on functional studies, we hypothesized that the trait self-esteem is associated with structural volumes of more than one brain region, hypothetically compatible with DMN related regions. Therefore, we predefined DMN associated structures (mPFC, PCC/PCu, IPL/TPJ, anterior cingulate cortex (ACC), and hippocampus) as the region of interest (ROI) areas.

METHOD

Participants

The Institutional Ethics Committee for Medical Studies of Ege University approved the study protocol (Dated: 16.10.2019/Decision no: 19-10.1T/49). Seventy-five healthy subjects (49 females, mean age=22.11 years; range: 18–25 years) from undergraduate classes at the same university were included in this study. Four subjects were excluded from the data due to psychiatric comorbidities. The participants were recruited from volunteer students aged between 20–25 at Ege University Faculty of Medicine who applied to the research advertisement. A psychiatrist (MCE) interviewed all participants using Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders (SCID) to exclude the participants with a psychiatric history (13). Exclusion criteria were (a) having any past or current neurological or psychiatric disorder diagnosis/treatment according to Diagnostic and Statistical Manual of Mental Disorders - Fifth Edition (DSM-5), (b) having any first-degree relative diagnosed with bipolar disorder or schizophrenia, (c) experienced head trauma history with amnesia, (d) having an unstable chronic medical illness, (e) being pregnant, (f) experienced significant childhood trauma (e.g., sexual or physical abuse). We were cautious about acquiring subjects from a homogenous sample pool/group of university students which might result in the normal distribution of our data. In addition, all participants had detailed information about the study and provided signed written informed consent before participating.

Assessment of Self-Esteem

We assessed each subject's trait self-esteem level using a validated Turkish form of Rosenberg Self-Esteem Scale (RSES) (14) which is broadly used as a global measure of trait self-esteem before structural MRI scanning (15). The 10-item scale measures self-worth and positive-or-negative feelings about the self. Participants indicated their agreement to each statement using a 4-point Likert-type scale (0–3 points). The maximum total score can be 30, with higher scores representing higher self-esteem.

MRI Data Acquisition

Structural imaging was performed on a 3T Siemens Magnetom Verio MR scanner equipped with a 12-channel head matrix coil (Syngo MR B17, Erlangen, Germany), at Ege University Hospital. Scanning was performed using a 3D T1-weighted, whole-head, sagittal, MPRAGE sequence (TR: 1600, FoV: 256 mm, slice thickness: 1 mm, Flip angle: 9°; voxel size: 1×1×1 160 slices). Its duration was eight minutes. 2D axial TSE sequences (TR: 2500, FoV: 200 mm, slice thickness: 5 mm, interslice gap: 1.8 mm, voxel size: 0.6×0.6×5 mm; 20 slices) and 3D coronal FLAIR sequences used for clinical evaluation under a supervision of a neuroradiologist.

Voxel-based Morphometry (VBM) Data Processing

We performed VBM analysis using the CAT12 toolbox (Wellcome Department of Cognitive Neurology; http://dbm.neuro.uni-jena.de/cat12) in SPM12 (Statistical Parametric Mapping, Welcome Trust Centre for Neuroimaging, http://www.fil.ion.ucl.ac.uk/spm) implemented in MATLAB R2019b. Firstly, anatomical images reoriented as the anterior commissure coordinate matched the origin point (0, 0, 0) in MNI space. Next, data preprocessing was performed using SPM12 via the pipeline based on recommendations for standardized VBM-analysis. First, all T1-weighted images were corrected for bias-field inhomogeneities and then spatially normalized by the CAT12 default DARTEL algorithm. After that, all images were segmented into grey matter (GM), white matter (WM), and cerebrospinal fluid (CSF). All preprocessed scans had been passed through an automated quality-check protocol. Finally, we smoothed all images with an 8 mm kernel (FWHM) via SPM12. Finally, smoothed GM images were used for the correlational analysis. None of the participants needed to be excluded due to the quality of their imaging data as well.

Statistical Analysis

We used Mann-Whitney U test to compare age, education levels, and RSES scores among gender. We evaluated the relationship between self-esteem levels and whole-brain GM volumes with multiple regression analysis in CAT12 toolbox: VBM-basic models. All RSES scores and GM volumes were checked for data cleaning, and outliers were dismissed thoroughly. The smoothed GM images and RSES scores were submitted as factors, and total intracranial volume (TIV), age, and gender were added as covariates. An absolute threshold for masking was 0.01. If a value in any of the images falls below the threshold at each voxel, then that voxel is excluded from the analysis. To test the a priori hypothesis regions, we performed ROI analysis at a cluster-forming height threshold (peak level) at $p<0.001$ (uncorrected) and the cluster-level threshold at $p<0.05$ (Family Wise Error (FWE)-corrected) with the size of 250 voxels (~ 0.5 cm^3) were set. The ROI mask for DMN (including hippocampi) was formed with AAL via WFU-PickAtlas (16). Finally, we did an additional exploratory analysis for the whole brain at $p<0.05$ with FWE corrections.

RESULTS

Female and male subjects' age and education levels did not differ significantly ($U=471$, $p>0.05$; $U=501$, $p>0.05$, respectively). The mean RSES score of the study sample was 23.03±4.06 (SD) ranging between 14–30 points with no difference among both genders ($U=568$, $p>0.05$).

Region of interest analyses revealed a large cluster at the right inferior parietal cortex (BA 39) extending to the angular gyrus positively correlated with self-esteem scores (Table 1, Figure 1a). The other associated brain regions with self-esteem were located in the medial cortical regions. Significant clusters were at the left precuneus/PCC (BA 31) (Figure 1b) and bilateral ACC, including right rostral ACC (Figure 1c) and bilateral dorsal ACC (Figure 1b and 1c). We could not observe any cluster at hippocampi even we reduced the cluster threshold to 25 voxels. The whole-brain exploratory analyses revealed only one cluster at right inferior parietal regions at the $p<0.05$ (FWE). There was no negative correlation between trait self-esteem and regional GM volumes at any ROI and whole-brain exploratory analyses.

DISCUSSION

In the present study, we investigated the relationship between trait self-esteem levels and grey matter volumes via VBM analysis. As expected, the degree of self-esteem levels correlated with the right temporoparietal junction/inferior parietal lobule (BA39), cortical midline regions at precuneus/PCC (BA31), rostral and dorsal anterior cingulate cortices (BA32). These regions are the parts of DMN that process self-related cognitive operations.

Table 1. Brain regions in which local grey matter volumes positively correlated with trait self-esteem (Voxel Size: 1.5 × 1.5 × 1.5 mm)

Brain region	Cluster size (voxel)	Coordinates			T	p
Right inferior parietal region (BA 39)	2600	46	-48	40	5.8	0.001*
Left precuneus/ PCC (BA 31)	537	-15	-56	45	4.6	<0.001
Right rACC (BA 32)	306	8	32	-2	4.4	<0.001
Left dACC (BA 32)	570	-8	27	18	4.4	<0.001

BA: Brodmann Area; dACC: dorsal anterior cingulate cortex; PCC: posterior cingulate cortex; rACC: rostral anterior cingulate cortex
* Family-wise error corrected.

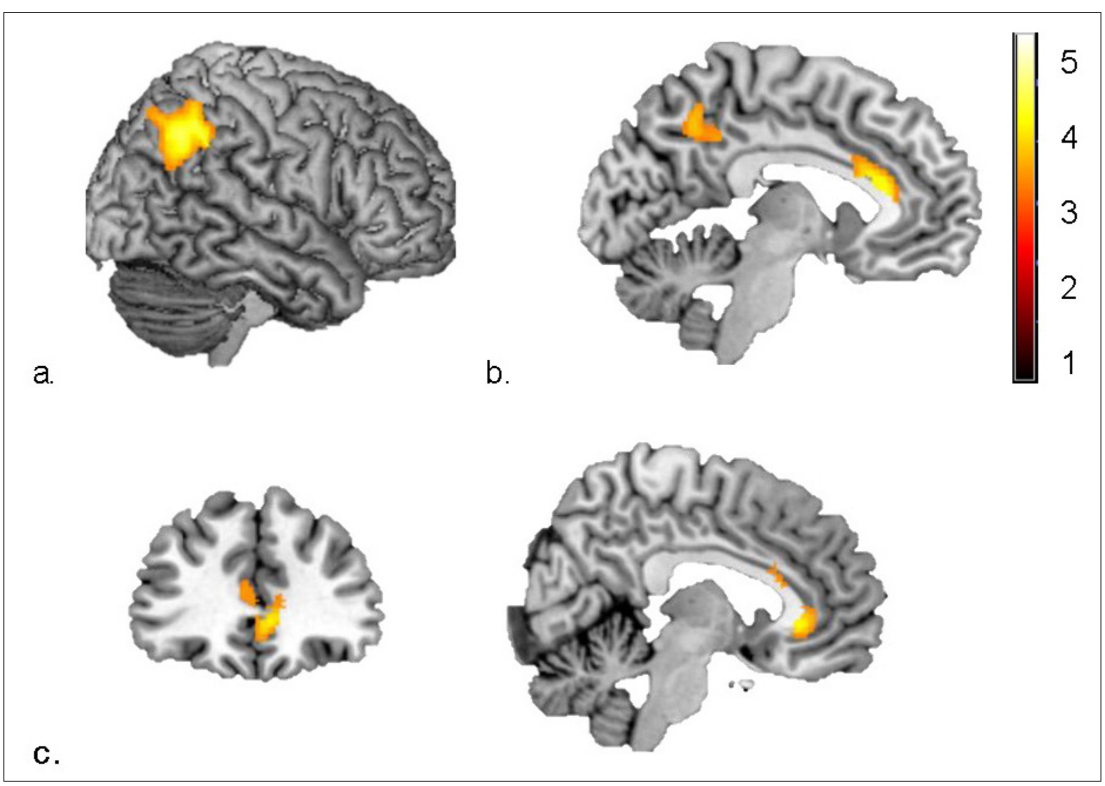

Figure 1. Self-esteem scores positively correlated with the clusters in the right inferior parietal lobule (temporoparietal junctionJ) (a). Other clusters were at the medial cortical structures in the precuneus/posterior cingulate cortex (b), rostral, and dorsal anterior cingulate areas (b,c).

Our findings extended the previous finding that the right TPJ volume is positively associated with self-esteem levels. There are functional studies suggesting that right TPJ (rTPJ) might be involved in self-esteem formation. For example, rTPJ is involved in positive self-evaluations and related to pride as a reflection of self-esteem and joy felt after achievements and positive inferences about appraisals of others about themselves (17). This function of rTPJ, combined with its role regarding the theory of mind– as in thinking about other's thoughts and therefore mentalization capacity– indicates that rTPJ may harbor a key role regarding the main construct of self-esteem (3). Furthermore, rTPJ /inferior parietal cortex is responsible for integrating internal and external sensorineural inputs to elucidate a coherent sense of self. This region's electrical stimulation or disruption may induce an out-of-body illusion and induce a dissociative perception (18). Thus, one can conclude that the greater grey matter volume of the rTPJ may represent a greater mentalization capacity (ToM) therefore eliciting an increased integration capacity of internal and external inputs for the processing of "self" (18).

We found a positive relationship between cortical midline regions at precuneus/PCC (BA31), rostral and dorsal anterior cingulate cortices (BA32). In line with our study, in literature, the core DMN– mPFC and PCC/PCu regions are mainly related to self-processing, internal mentation, and autobiographical memory recall (19). The posterior cortical midline regions (PCu and PCC (BA 31)) which have direct interactions with almost all DMN nodes are also involved in the production of self-referential mental thoughts and self-consciousness (20). Supporting this possible relationship, an alteration at the intrinsic functional correlation between PCC/PCu, mPFC, and right IPL is shown in autism cases where self-concept is hardly formed and self-esteem cannot be evaluated properly (21). In contrast to this, indicated a 'conflicting' negative relationship between Kong et. al (2015) (22) the grey matter volume of precuneus and a measure of life satisfaction mediated by self-esteem. In spite of their results, they also stated that most other studies showed a positive correlation in terms of grey matter volume and self-esteem finally emphasizing that this conflicting negative relationship might be detected due to intracortical myelination and synaptic pruning during the development (23).

Among the frontal cortical midline regions of DMN, perigenual ACC is specialized to 'self' while other regions represent both familiar and non-familiar 'other' subjects (24). Lieberman et al. (2019) (25) showed evidence that the anteromedial prefrontal cortex (amPFC) executes self-related processes. Our finding of the correlation between pregenual ACC as a subdivision of amPFC and self-esteem supported the idea that the perigenual ACC is most likely involved in self-processing and self-esteem.

In our study, we could not find any association between hippocampal volumes and trait self-esteem scores. It is known that several factors might affect hippocampal volume, including age, cortisol levels, depression, and education (11). Our sample consisted of a relatively homogenous group of young, healthy individuals with similar education levels. Therefore, sociodemographic and other factors associated with hippocampal volume differences between samples might lead to inconsistent results between the studies.

It is well known that low self-esteem is common among people with depression and depressed patients have many structural gray matter volume alterations compared to healthy people (26). The structures associated with trait self-esteem might be altered before the subjects become depressed. Therefore, the structural alterations in subjects with low self-esteem could increase the susceptibility to depression. Although the altered functionality of DMN in depression has not been fully proven yet, some studies suggest that the DMN might be connected with the ruminations of depressive patients (27). Ruminations are recurrent negative thoughts leading to altered apprehension about life quality and diminished cognitive processing (28). In a longitudinal study, Kuster et al. (2012) (29) showed that ruminations in subjects with low self-esteem might predict the subsequent depression. Therefore, explaining the neural basis of increased ruminations affecting perceived happiness in depressive patients may help us understand the neurophysiological basis of decreased perceived self-worth in this population.

Our study has many limitations. First, our sample mainly consisted of young university students with an unequal male-female ratio. Thus, one should be cautious while inferring our results to the general population. Although our sample size is the largest in the volumetric structural studies for self-esteem, it is still modest. Structural MRI studies of personality traits (e.g., self-esteem in our study) might be troubled with low specificity of the personality trait definitions and lead to inconsistent results. Although self-esteem is one of the well-defined and most studied personality traits, the direction of causation between self-esteem and brain structure cannot be precisely determined (22). Advanced neuroimaging modalities should be used in order to scrutinize the indicated regions in a more detailed manner.

As a conclusion, our findings revealed that cognitive operations under the formation of trait self-esteem are structurally inherent with DMN regions of PCC/Pcu, ACC, and rTPJ. Our structural findings are in line with the results of previous functional studies indicating the function of self-esteem as a higher-order cognitive ability encompassing a network of diverse brain areas. This study provides insight in understanding the neurobiological basis of many psychiatric disorders, according to literature, especially major depression, by focusing on the association between regional grey matter volumes and self-esteem as a predisposing trait that changes brain structure.

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Data Sharing Statement: Our study's data cannot be shared publicly due to legal restrictions as participants have led us use their neuroimaging data exclusive to this study.

Ethics Committee Approval: The Institutional Ethics Committee for Medical Studies of Ege University approved the study protocol (Dated: 16.10.2019/Decision no: 19–10.1T/49).

Informed Consent: All participants had detailed information about the study and provided signed written informed consent before participating.

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REFERENCES

1. Sadock BJ, Ruiz P, Sadock VA. Kaplan & Sadock's Comprehensive Textbook of Psychiatry. US: Lippincott Williams & Wilkins; 2017.
2. Yang J, Dedovic K, Chen W, Zhang Q. Self-esteem modulates dorsal anterior cingulate cortical response in self-referential processing. Neuropsychologia. 2012;50:1267–1270. [Crossref]
3. Agroskin D, Klackl J, Jonas E. The self-liking brain: a VBM study on the structural substrate of self-esteem (Siegel A, editor). PLoS One. 2014;9:e86430. [Crossref]

4. Sowislo JF, Orth U. Does low self-esteem predict depression and anxiety? A meta-analysis of longitudinal studies. Psychol Bull. 2013;139:213–240. [Crossref]
5. Zeigler-Hill V. The connections between self-esteem and psychopathology. J Contemp Psychother. 2011;41:157–164. [Crossref]
6. Eisenberger NI, Inagaki TK, Muscatell KA, Haltom KEB, Leary MR. The neural sociometer: brain mechanisms underlying state self-esteem. J Cogn Neurosci. 2011;23:3448–3455. [Crossref]
7. Yang J, Xu X, Chen Y, Shi Z, Han S. Trait self-esteem and neural activities related to self-evaluation and social feedback. Sci Rep. 2016;6:20274. [Crossref]
8. Pan W, Liu C, Yang Q, Gu Y, Yin S, Chen A. The neural basis of trait self-esteem revealed by the amplitude of low-frequency fluctuations and resting state functional connectivity. Soc Cogn Affect Neurosci. 2016;11:367–376. [Crossref]
9. Dohmatob E, Dumas G, Bzdok D. Dark control: the default mode network as a reinforcement learning agent. Hum Brain Mapp. 2020;41:3318–3341. [Crossref]
10. Zhuo F, Zhu S, Shi H, Hu S, Cai H, Korczykowski M, et al. Default mode network CBF predicts individual differences in self-esteem. Proc Intl Soc Mag Reson Med 2013;21:3292. https://archive.ismrm.org/2013/3292.html
11. Huanhua L, Li X, Wang Y, Song Y, Liu J. The hippocampus underlies the association between self-esteem and physical health. Sci Rep. 2018;8:17141. [Crossref]
12. Yarkoni T. Big correlations in little studies: inflated FMRI correlations reflect low statistical power -commentary on Vul, et al. (2009). Perspect Psychol Sci. 2009;4:294–298. [Crossref]
13. First MB. Structured Clinical Interview for the DSM (SCID). In: Cautin RL, Lilienfeld SO, editors. The Encyclopedia of Clinical Psychology. John Wiley & Sons, Inc.; 2015. p.1-6. [Crossref]
14. Çuhadaroğlu F. Adolesanda Benlik Saygısı. Hacettepe Üniversitesi Tıp Fakültesi Psikiyatri Anabilim Dalı, Yayımlanmamış Uzmanlık Tezi, Ankara; 1986.
15. Rosenberg M. Society and the Adolescent Self-Image. Princeton NJ: Princeton University Press; 1965. [Crossref]
16. Tzourio-Mazoyer N, Landeau B, Papathanassiou D, Crivello F, Etard O, Delcroix N, et al. Automated anatomical labeling of activations in SPM using a macroscopic anatomical parcellation of the MNI MRI single-subject brain. Neuroimage. 2002;15:273–289. [Crossref]
17. Leary MR. Motivational and emotional aspects of the self. Annu Rev Psychol. 2007;58:317–344. [Crossref]
18. Igelström KM, Graziano MSA. The inferior parietal lobule and temporoparietal junction: a network perspective. Neuropsychologia. 2017;105:70–83. [Crossref]
19. Fuentes-Claramonte P, Martín-Subero M, Salgado-Pineda P, Alonso-Lana S, Moreno-Alcázar A, Argila-Plaza I, et al. Shared and differential default-mode related patterns of activity in an autobiographical, a self-referential and an attentional task. PloS One. 2019;14:e0209376. [Crossref]
20. Brewer JA, Garrison KA, Whitfield-Gabrieli S. What about the "self" is processed in the posterior cingulate cortex?. Front Hum Neurosci. 2013;7:647. [Crossref]
21. Kennedy DP, Courchesne E. The intrinsic functional organization of the brain is altered in autism. Neuroimage. 2008;39:1877–1885. [Crossref]
22. Feng K, Ding K, Yang Z, Dang X, Hu S, Song Y, et al. Examining gray matter structures associated with individual differences in global life satisfaction in a large sample of young adults. Soc Cogn Affect Neurosci. 2015;10:952–960. [Crossref]
23. Paus T. Mapping brain maturation and cognitive development during adolescence. Trends Cogn Sci. 2005;9:60–68. [Crossref]
24. Qin P, Northoff G. How is our self related to midline regions and the default-mode network? Neuroimage. 2011;57:1221–1233. [Crossref]
25. Lieberman MD, Straccia MA, Meyer ML, Du M, Tan KM. Social, self, (situational), and affective processes in medial prefrontal cortex (MPFC): causal, multivariate, and reverse inference evidence. Neurosci Biobehav Rev. 2019;99:311–328. [Crossref]
26. Bora E, Fornito A, Pantelis C, Yücel M. Gray matter abnormalities in major depressive disorder: a meta-analysis of voxel based morphometry studies. J Affect Disord. 2012;138:9–18. [Crossref]
27. Zhou H-X, Chen X, Shen Y-Q, Li L, Chen N-X, Zhu Z-C, et al. Rumination and the default mode network: meta-analysis of brain imaging studies and implications for depression. Neuroimage 2020;206:116287. [Crossref]
28. Luo Y, Kong F, Qi S, You X, Huang X. Resting-state functional connectivity of the default mode network associated with happiness. Soc Cogn Affect Neurosci. 2016;11:516–524. [Crossref]
29. Farah K, Orth U, Meier LL. Rumination mediates the prospective effect of low self-esteem on depression: a five-wave longitudinal study. Pers Soc Psychol Bull. 2012;38:747–759. [Crossref]