Pleasure attainment or self-realization: the balance between two forms of well-beings are encoded in default mode network

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Abstract

What is a good life and how it can be achieved is one of the fundamental issues. When considering a good life, there is a division between hedonic (pleasure attainment) and eudaimonic well-being (meaning pursuing and self-realization). However, an integrated approach that can compare the brain functional and structural differences of these two forms of well-being is lacking. Here, we investigated how the individual tendency to eudaimonic well-being relative to hedonic well-being, measured using eudaimonic and hedonic balance (EHB) index, is reflected in the functional and structural features of a key network of well-being—the default mode network (DMN). We found that EHB was positively correlated with functional connectivity of bilateral ventral medial prefrontal cortex within anterior DMN and bilateral precuneus within posterior DMN. Brain morphometric analysis showed that EHB was also positively correlated with gray matter volume in left precuneus. These results demonstrated that the relative dominance of one form of well-being to the other is reflected in the morphometric characteristics and intrinsic functions of DMN.

Key words: eudaimonic and hedonic balance; eudaimonic well-being; hedonic well-being; default mode network; functional connectivity; voxel-based morphometry

Introduction

What is a good life and how it can be achieved is one of the fundamental issues, which has a great impact on our practices to make human society better (Ryan and Deci, 2001; Huta and Waterman, 2013). Dating back to ancient Greece, significant strides have been made in distinguishing between hedonic and eudaimonic well-being when considering the nature of a good life (Ryan and Deci, 2001). The hedonic approach focuses on happiness and defines well-being as pleasure attainment. In contrast, the eudaimonic approach defines well-being in terms of meaning, purpose, self-potential and self-realization (Waterman, 1993; Ryan and Deci, 2001). As each form of well-being provides different answers to what a good life is, revealing the brain mechanisms of hedonic and eudaimonic well-being holds promise for enriching our comprehension of well-being.

Psychologically, hedonic well-being relates more strongly to excitement-seeking, extraversion and present-orientated, whereas eudaimonic well-being relates more strongly to self-connection, introversion and temporal integration (Huta and Ryan, 2010; Huta, 2012; Baumeister *et al.*, 2013). For example, compared to individuals with hedonic well-being dominance, individuals with eudaimonic well-being dominance devoted more time to self-reflection to identify one's true self (Huta, 2012) and thought more frequently about their past and future (Baumeister *et al.*, 2013). These characteristics of hedonic and eudaimonic well-being are in line with functions of the default mode network (DMN), i.e. introspectively oriented mental activity at rest (e.g. self-reflection, theory of mind, mind wandering, episodic memory and future episodic thought) (Raichle *et al.*, 2001; Buckner *et al.*, 2008).

Recent neuroimaging studies on well-being have revealed neural correlates of hedonic or eudaimonic well-being within and outside of DMN (Heller *et al.*, 2013; Lewis *et al.*, 2014; Luo *et al.*, 2014; Kong *et al.*, 2015, 2016; Sato *et al.*, 2015). For example, our previous study using resting-state functional magnetic resonance imaging (R-fMRI) approach found that the hedonic well-being was associated with decreased resting-state functional connectivity (RSFC) within core areas of DMN (Luo *et al.*, 2016). Self-reported meaning in life was shown positively correlated with connectivity of medial temporal lobe, a subnetwork of the DMN (Waytz *et al.*, 2015). As core regions of DMN, such as medial prefrontal cortex (MPFC), not only involved in pleasure attachment, but also implicated in self-representation, introspective self-referential cognition and consciousness, DMN may play a fundamental role in connecting hedonic and eudaimonic well-being (Kringelbach and Berridge, 2009).

To date, few study have examined hedonic and eudaimonic well-being in a single study. The only pioneering study using resting-state electroecncephalography found that greater left than right superior frontal activation was positively associated with both forms of well-being, and left frontal activation predicted eudaimonic but not hedonic well-being when positive affect is statistically controlled (Urry *et al.*, 2004). Thus, an integrated approach that can compare the functional and structural differences of these two forms of well-being with high spatial resolution is lacking.

Here, we filled this gap by using structural and functional MRI techniques and an eudaimonic and hedonic balance (EHB) index. Conceptually, EHB quantifies the balance between eudaimonic and hedonic well-being, or in other words, which form of well-being is more dominant. This could be an interesting trait that shows meaningful individual differences. Operationally, it is defined as the difference between Z-standardized scores of Psychological Well-being and the Positive Affect subscale of the Positive and Negative Affect Schedule (PANAS). This definition is based on the approach used in Cox *et al.* (2012), which measures the balance between affective empathy and cognitive empathy. EHB index has high ecological validity and reflects the fact that individuals live with both hedonic and eudaimonic well-being in daily life, though some with greater tendency to pursue pleasure and others with greater tendency to self-realization. Using EHB index is necessary also because it allows us to investigate eudaimonic and hedonic well-being integrally, even when two measures were highly correlated.

Previous studies reported that eudaimonic well-being, relative to hedonic well-being, is correlated more strongly with self, and past or future thinking (Huta and Ryan, 2010; Huta, 2012; Baumeister *et al.*, 2013). Thus, we predicted that EHB score will be positively correlated with functional connectivity of core

DMN areas implicated in these functions, such as MPFC and precuneus (Raichle *et al.*, 2001; Buckner *et al.*, 2008; Andrews-Hanna *et al.*, 2010). That is, a eudaimonic dominance would exhibited enhanced functional connectivity within DMN and a hedonic dominance would exhibited decreased DMN functional connectivity. Furthermore, as eudaimonic or hedonic dominance is a relatively stable trait, EHB may also be associated with structural features within the DMN. Thus, we predicted that EHB would be related to DMN morphometry, such as gray matter volume.

Materials and Methods

Participants

Participants were 154 healthy undergraduate or postgraduate students, who volunteered as part of an ongoing study investigating the association between brain imaging, temporal cognition and well-being (Luo *et al.*, 2014, 2016). Fourteen participants were excluded due to excessive head motion (see Functional MRI data preprocessing and analyses section for details), and another two were excluded due to missing self-report measures. Final sample includes 138 participants (males/females, 52/86; mean age = 21.10 ± 1.69). All participants were right-handed and had normal or corrected-to-normal vision, with no history of neurological conditions or psychiatric episodes. In accordance with the Declaration of Helsinki, written informed consent was obtained from all participants. The study protocol was approved by the Southwest University Brain Imaging Center Institutional Review Board.

Eudaimonic and hedonic balance

We used EHB to quantify the tendency to eudaimonic or hedonic well-being. The EHB index, a relative measure, was defined as the difference between eudaimonic and hedonic well-being. A positive EHB score indicates a dominance of eudaimonic well-being, while a negative EHB score indicates a dominance of hedonic well-being. The trait level of hedonic well-being was measured using the Positive Affect subscales of the PANAS (Watson *et al.*, 1988; Heller *et al.*, 2013), a measure of hedonic well-being with high reliability (Cronbach's = 0.87).

The trait level of eudaimonic well-being was assessed using the Chinese version of the 42-item Psychological Well-being (Ryff, 1989), a reliable measure of eudaimonic well-being (Heller *et al.*, 2013; Lewis *et al.*, 2014; Kong *et al.*, 2015). In our sample, a good reliability was also observed (Cronbach's α = 0.92). The eudaimonic well-being can be further divided into two components: self- and other-focused eudaimonic well-being. The self-focused eudaimonic well-being index is composed of environmental mastery, personal growth, purpose in life and self-acceptance (Cronbach's α = 0.90). Other-focused eudaimonic well-being index is composed of positive relations with others (Cronbach's α = 0.79) (Barrett-Cheetham *et al.*, 2016). The correlation between hedonic and eudaimonic well-being was shown in Figure 1.

Imaging data acquisition

Imaging data were acquired on a 3.0-T scanner (Magnetom Trio, Siemens, Erlangen, Germany). Eight minutes of functional images were acquired using a single-shot, gradient-recalled echo planar imaging sequence (TR = 2000 ms, TE = 30 ms, flip angle = 90°, 32 axial slices, FOV = 192 × 192 cm, acquisition matrix = 64 × 64, slice thickness = 3 mm, without gap, voxel
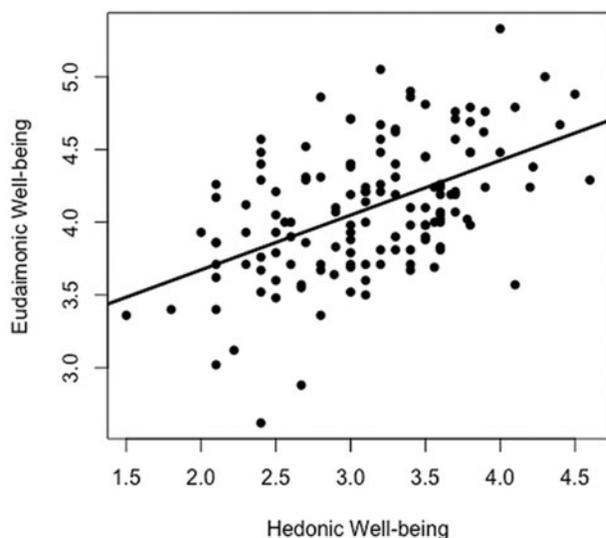
Fig. 1. Correlations between hedonic and eudaimonic well-being.

size $= 3 \times 3 \times 4$ mm), when participants were instructed to rest with their eyes closed, not to think of anything in particular and not to fall asleep. To minimize head motion, participants' head were restricted with foam cushions. High-resolution T1-weighted anatomical images were also acquired in sagittal orientation using a 3D magnetization prepared rapid gradient-echo sequence (176 slices, TR $= 1900$ ms, TE $= 2.53$ ms, flip angle $= 9°$, resolution $= 256 \times 256$ and voxel size $= 1 \times 1 \times 1$ mm).

Functional MRI data preprocessing and analyses

Preprocessing. Functional images were preprocessed using data processing assistant and R-fMRI (version 2.2, http://www.rest fmri.net/forum/DPARSF) (Chao-Gan and Yu-Feng, 2010). The preprocessing steps included slice timing, head motion correction, spatial normalization and smoothing (4 mm full-width at half maximum Gaussian kernel).

As head motion is a major concern for R-fMRI data analyses, we controlled head motion at different levels. First, we performed outlier analyses based on mean framewise displacement (FD), a summary measure of overall head motion (Power *et al.*, 2012). Eight participants were excluded due to head motion outside of 1.5 s.d. of the group mean (0.122 ± 0.061 mm, threshold $= 0.214$ mm); second, we checked the number of volumes with an FD < 0.2 mm for each participant. Six participants were excluded due to having < 150 volumes with FD < 0.20 mm (Power *et al.*, 2012); finally, we included mean FD in the group analysis as a nuisance regressor to account for the residual effect of motion.

DMN identification. After preprocessing, we concatenated the image data of 138 participants and performed group spatial independent component analysis (ICA) on the concatenated data to separate fMRI signal into spatially independent networks using Group ICA of fMRI Toolbox (GIFT) (icatb.sourceforge.net) (Calhoun *et al.*, 2001). The optimal number of components was set to 32, according to the minimum description length criteria for source estimation (Li *et al.*, 2007). To perform group ICA, dimensionality of the data was first reduced using principle component analysis. Then, the reduced data were concatenated over the time domain using the infomax algorithm. To ensure

the reliability of the derived components, the infomax algorithm was repeated 20 times by running the ICASSO toolbox, using both 'randinit' and 'bootstrap' methods (Himberg *et al.*, 2004). Individual maps and time courses for each participant were then back-reconstructed and calibrated using Z values to normalize the signal. As Z values represented the contribution of the voxels to the independent component, it is commonly thought that Z values can be indirectly used to measure the functional connectivity within the network (Beckmann *et al.*, 2005; Liao *et al.*, 2010).

Components corresponding to the DMN were identified in two steps: first, we performed a spatial template matching procedure using a DMN template delineated by Smith *et al.* (2009). Two components having the highest spatial overlap with the template were identified ($r = 0.32$ and 0.17). Then, these two components were further confirmed by visual inspection and guided by previously reported DMN (Buckner *et al.*, 2008; Andrews-Hanna *et al.*, 2010). One component mainly includes MPFC, anterior and posterior cingulate cortex (ACC/PCC) (anterior DMN: aDMN), and the other includes precuneus and PCC (posterior DMN: pDMN) (Figure 2). The stability of these two components were both above 0.97 assessed using ICASSO.

Association between DMN intrinsic functional connectivity and the balance of well-beings. Statistical analyses were performed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/). To associate functional connectivity of DMN with EHB, multiple regression analyses were performed. First, for each DMN component, individual maps of all participants were entered into random effect one-sample *t*-tests (family-wise error, $P < 0.05$, $k > 20$) and create a sample-specific component map (Figure 2). Each component map was used as a mask in the group analysis to restrict the results within DMN areas. Second, we carried out multiple regression analysis with EHB as the covariate of interests, and gender, age and mean FD as nuisance covariates. Multiple comparisons were corrected using 10 000 Monte Carlo simulation (Ledberg *et al.*, 1998), implemented in AlphaSim program within AFNI (http://afni.nimh.nih.gov/pub/dist/doc/program_help/AlphaSim.html) ($P < 0.05$, minimum cluster size are 30 voxels/810 mm^3 and 27 voxels/729 mm^3 for aDMN and pDMN, respectively).

Secondary analyses. In addition to EHB, we performed secondary analyses to examine the unique effect associated with hedonic after controlling for eudaimonic well-being and vice versa. Although two forms of well-beings are highly correlated, no multicollinearity among the regressors were found when both forms of well-beings were entered into the same general linear model (variance inflation factor was 1.52, below the cutoff criterion of 5) (Studenmund, 2000). Age, gender and head motion were included as nuisance covariates. Multiple comparison correction procedure was identical to the EHB analyses.

Specificity analyses. To confirm the specificity of our results, we performed additional two sets of analyses. First, we examined whether DMN connectivity was associated with measures other than EHB, such as anxious arousal. Anxious arousal is measured using the Anxious Arousal subscale of Mood and Anxiety symptom Questionnaire (Clark and Watson, 1991). This subscale is composed of 17 items and measures the level of somatic tension and hyperarousal (Cronbach's $\alpha = 0.77$). We chose this measure because it has no direct relationship with hedonic or eudaimonic well-being. Second, we examined whether EHB was associated with functional connectivity of networks other than
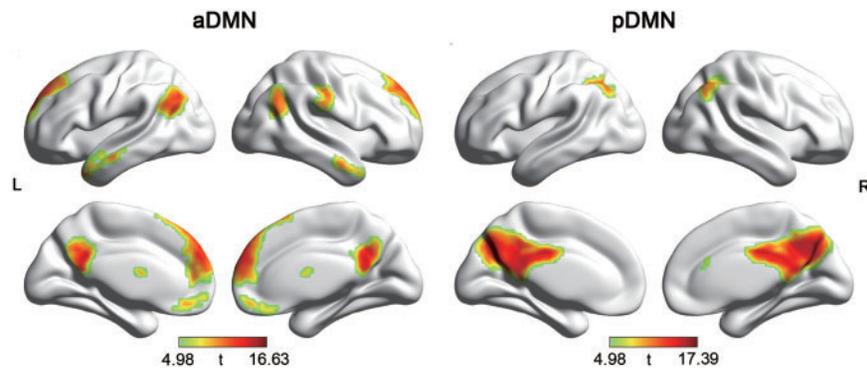
Fig. 2. Spatial pattern of aDMN and pDMN. L, left; R, right.

DMN. We chose two visual networks (medial and lateral visual networks) for this purpose (see Supplementary Figure S1 for spatial map of medial and lateral visual networks). The regression analyses and multiple comparison correction were identical to the main EHB and DMN analyses.

Structural MRI data preprocessing and analyses: voxel-based morphometry

To examine the anatomical basis underlying the association between EHB and DMN functional connectivity, we performed voxel-based morphometry (VBM) analysis using FSL-VBM (Douaud *et al.*, 2007, http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FSLVBM), an optimized VBM protocol (Good *et al.*, 2001; Smith *et al.*, 2004). Preprocessing included brain extraction, gray matter segmentations and non-linear registration to Montreal Neurological Institute (MNI) 152 standard space. Then, the gray matter segmented images were used to create a study-specific template. After that, all native gray matter images were non-linearly registered to this template and 'modulated' to correct for local expansion (or contraction) due to the non-linear component of the spatial transformation. The modulated gray matter images were then smoothed with an isotropic Gaussian kernel with a sigma of 3 mm.

The group analyses were restricted within three spherical region of interests (ROIs) (radius = 8 mm), defined based on the peak voxel coordinates in the RSFC analysis. Non-parametric voxel-wise statistical testing was performed using FSL randomize with 5000 permutations. Regressors include EHB, gender and age. Cluster significance was determined using the threshold-free cluster enhancement techniques (Smith and Nichols, 2009). The number of ROIs ($n = 3$) was also Bonferroni corrected ($P < 0.05/3 = 0.017$). Lastly, the VBM values of the 'survived' ROIs were correlated with its RSFC values to test for the structural and functional association.

Results

Behavioral measures of well-being

The sample demographics were showed in Table 1. There is no significant correlation between EHB and participant measures, including age, sex and head motion ($P > 0.10$). Hedonic (3.12 ± 0.61) and eudaimonic well-being (4.09 ± 0.46) scores were moderately correlated ($r = 0.51$, $P < 0.001$) (Figure 1). EHB scores range from −2.76 to 2.22. The percent of participants showing eudaimonic and hedonic dominance were close (50.7 *vs* 49.3%).

Table 1. Demographics

	Mean ± s.d.	Range	r/t (P value)
Age (year)	21.10 ± 1.69	18–25	−0.14 (0.11)
Female sex, %	62.3%		−0.54 (0.59)
Head motion (mm)	0.108 ± 0.038	0.04–0.22	0.07 (0.39)
Eudaimonic well-being	4.09 ± 0.46	2.62–5.33	0.50 (<0.001)
Hedonic well-being	3.12 ± 0.61	1.5–4.6	0.50 (<0.001)
EHB	0.00 ± 1.00	−2.76–2.22	

Note: $n = 138$. For continuous variables, Pearson's correlation between demographic variable and EHB was computed. For categorical variable (i.e. sex), independent samples t-Test were performed to test for the group differences in EHB.

DMN intrinsic functional connectivity and the balance of well-beings

Spatial pattern of DMNs obtained from the group ICA analyses are shown in Figure 2 on surface map using BrainNet Viewer (Xia *et al.*, 2013). Visual inspection indicated that the aDMN was mainly composed of the MPFC, ACC, a small portion of the PCC/precuneus, and bilateral inferior parietal gyrus. The pDMN mainly included the PCC and precuneus.

Multiple regression analysis indicated that the Z values of the bilateral vMPFC (portion of the aDMN) were positively correlated with EHB, and the Z values of the bilateral precuneus (portion of the pDMN) were also positively correlated with EHB (Figure 3A, Table 2). That is, individuals with greater eudaimonic dominance had greater DMN connectivity and individuals with greater hedonic dominance had smaller DMN connectivity.

As a large body of literature showed that DMN hyperconnectivity was associated with rumination and depression (Greicius *et al.*, 2007; Sheline *et al.*, 2010; Berman *et al.*, 2011; Whitfield-Gabrieli and Ford, 2012), we further disentangle the functional significance of DMN hyperconnectivity by correlating the DMN connectivity strength with two subcomponents of eudaimonic well-being. Specifically, we extracted the connectivity strength from regions showing significant associations with eudaimonic well-being (after controlling for hedonic well-being) and conducted Person's correlation between their connectivity and the two subscales of eudaimonic well-being. We found that the Z values of the vMPFC were positively correlated with the self-focused eudaimonic well-being ($r = 0.17$, $P = 0.046$) but not other-focused eudaimonic well-being ($r = 0.11$, $P > 0.05$). The same pattern was observed for the left precuneus: correlation was significant for self-focused eudaimonic well-being ($r = 0.19$,
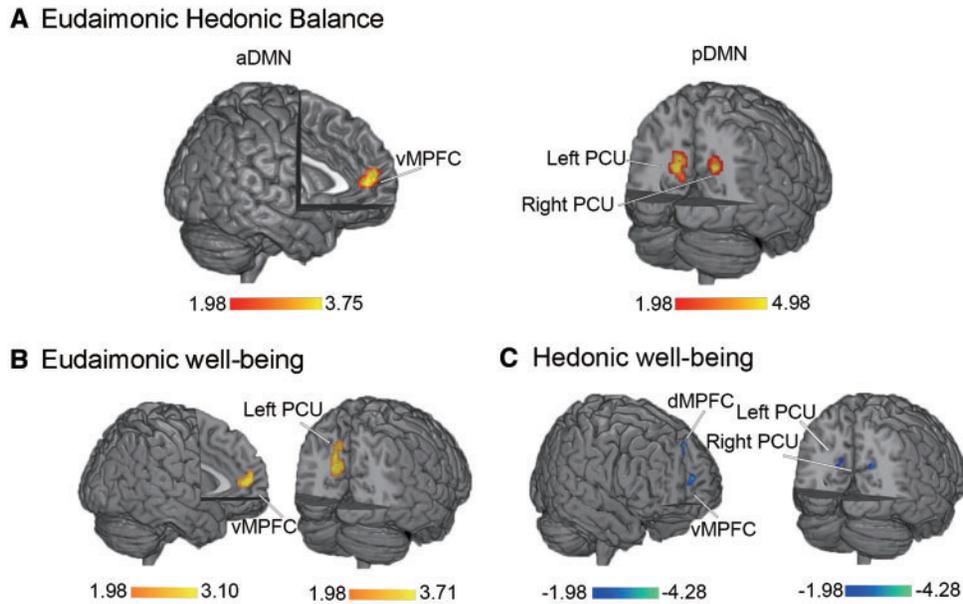
Fig. 3. aDMN and pDMN regions where functional connectivity is correlated with EHB (A), eudaimonic (B) or hedonic well-being (C). vMPFC, ventral MPFC; dMPFC, dorsal MPFC; PCU, precuneus.

Table 2. DMN regions where within network functional connectivity is significantly correlated with EHB, hedonic well-being, or eudaimonic well-being

	Anatomical region	Side	BAs	MNI			Voxel	Peak
				x	y	z	Size	t-value
EHB	aDMN							
	Ventral MPFC	B	10	−6	54	12	40	3.75
	pDMN							
	Precuneus	L	31	−15	−63	21	67	4.08
	Precuneus	R	31	21	−54	27	36	4.51
Hedonic well-being	aDMN							
	Ventral MPFC	B	10	−6	54	12	32	−4.08
	Dorsal MPFC	B	9	6	48	42	47	−4.28
	pDMN							
	Precuneus	L	31	−15	−66	21	48	−3.35
	Precuneus	R	31	18	−54	27	54	−4.28
Eudaimonic well-being	aDMN							
	Ventral MPFC	B	10	−6	51	9	34	3.10
	pDMN							
	Precuneus	L	31	−15	−63	21	70	3.72

Note: Side refers to the hemisphere (B, bilateral; R, right; L, left). Brodmann areas (BAs), coordinates of peak *t*-value in MNI space, volume in voxels and peak *t*-values are specified for each region showing significant correlations.

$P = 0.023$) but not for other-focused eudaimonic well-being ($r = 0.01$, $P > 0.05$) (Figure 4).

Consistent with our primary analyses, secondary analyses showed that eudaimonic well-being was positively correlated with intrinsic functional connectivity of vMPFC and precuneus after controlling for hedonic well-being (Figure 3B, Table 2). In contrast, hedonic well-being was negatively correlated with functional connectivity of dMPFC, vMPFC and precuneus after controlling for eudaimonic well-being (Figure 3C, Table 2). Our specificity analyses indicated that DMN functional connectivity was not significantly associated with anxious arousal; Furthermore, the functional connectivity of visual networks were not correlated with EHB. These results provide additional evidence to support that the correlations between EHB and DMN functional connectivity are specific.

VBM and the balance of well-being

ROI-based analyses revealed a significant positive correlation between EHB and gray matter volume of the left precuneus (MNI coordinate: −14, −70, 20; cluster size = 100, $P = 0.003$, Bonferroni corrected) (Figure 5). No significant correlations were found between bilateral vMPFC or right precuneus and EHB. The gray matter volume value of left precuneus was marginally correlated with its RSFC values ($r = 0.15$, $P = 0.075$).

Discussion

In the present work, we used structural and R-fMRI to investigate how predominance of a certain form of well-being is reflected in the functional and structural characteristics of DMN.
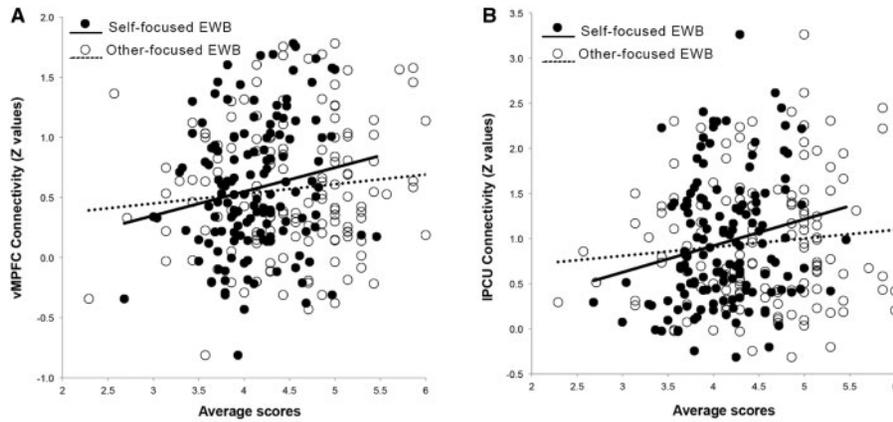
Fig. 4. Correlations between self- and other-focused eudaimonic well-being (EWB) and DMN functional connectivity: vMPFC (A) and precunues (B).
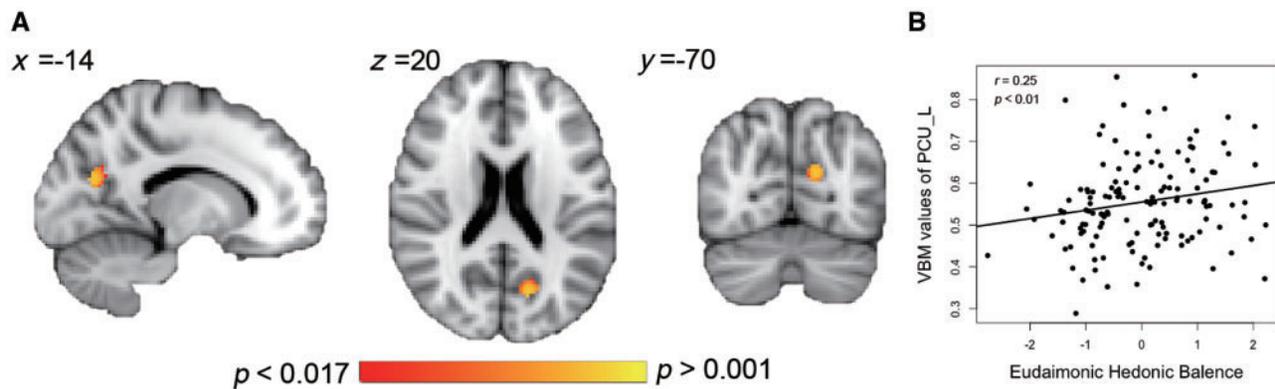

Fig. 5. VBM analyses. (A) DMN subregions where gray matter volume is significantly correlated with EHB. (B) Correlations between EHB and gray matter volume of the left precuneus (PCU_L).

We demonstrated that EHB were positively correlated with the intrinsic functional connectivity of bilateral vMPFC within aDMN and bilateral precuneus within pDMN. Furthermore, our brain morphometry analysis highlighted the association between gray matter volume in the left precuneus and EHB. These results provided novel evidence to support the role of DMN in one's inclination toward hedonic or eudaimonic well-being.

Our primary and secondary analyses highlighted the role of vMPFC and precuneous hyperconnectivity in eudaimonic well-being dominance and eudaimonic well-being alone. These results seem to contradict with previous work on hedonic well-being and the depression literature (Greicius *et al.*, 2007; Sheline *et al.*, 2010; Berman *et al.*, 2011; Whitfield-Gabrieli and Ford, 2012) but are consistent with a recent eudaimonic well-being study (Waytz *et al.*, 2015), which showed that meaning in life was positively correlated with a subnetwork of the DMN. When decomposing eudaimonic well-being into self-focus and other-focus well-being, we found that DMN hyperconnectivity was only correlated with self-focus but not other-focus well-being.

Self-focused attention can be adaptive (i.e. self-reflection) or maladaptive (i.e. self-rumination). Self-reflection is a form of positive self-focus that is motivated by curiosity or epistemic interest in the self and confers benefits to mental health; whereas, self-rumination is a form of negative, chronic self-focus is motivated by perceived threat, losses to the self and is associated with depression and neuroticism (Trapnell and Campbell, 1999; Takano and Tanno, 2009). As eudaimonic well-being is associated with higher level of adaptation and mental health, and more self-connected (Huta, 2012; Baumeister *et al.*, 2013), it is possible that people with higher levels of eudaimonic well-being frequently engaged in self-reflection, rather than self-rumination. Thus, our results of EHB and eudaimonic well-being support the idea that the functional role of DMN is not limited to maladaptation and lower level of well-being but also to adaptation and higher level of well-being.

We found that eudaimonic dominance (a high positive EHB score) is not only associated with higher intrinsic functional connectivity but also with larger gray matter volume in precuneus. The convergence between structural and functional results in precuneus indicates that the observed association between intrinsic functional connectivity, and EHB could be partially explained by the gray matter volume. This convergence also highlights the critical role of precuneus in the stable trait of balance between eudaimonic and hedonic well-being. Precunues, the posterior core of DMN, subserves visuospatial imagery, episodic memory retrieval and episodic future thought (Cavanna and Trimble, 2006; Schacter *et al.*, 2007; Fransson and Marrelec, 2008; Uddin *et al.*, 2009). Functionally, the overall connectivity of pDMN was shown positively correlated with meaning in life, a core feature in eudaimonic well-being (Waytz *et al.*, 2015). Structurally, gray matter volume of precuneus was shown positively correlated with the emotional intensity and purpose in life (Sato *et al.*, 2015). In contrast, decreased functional connectivity of medial parietal cortex was associated with the inclination to hedonic well-being (Luo *et al.*, 2016).

As thinking about past and future *vs* the present enhances the meaning of life or eudaimonic well-being (Routledge *et al*., 2011; Waytz *et al*., 2015; Sedikides *et al*., 2016), increased intrinsic functional connectivity of pDMN may indicate that people with eudaimonic dominance are more likely to beyond here and now and draw meaning from past or future events (Baumeister *et al*., 2013), which in turn enhances the feeling of purpose and meaningfulness (Waytz *et al*., 2015).

Our EHB-related results replicated and extended previous work examining either hedonic or eudaimonic well-being. Our work suggests that EHB is a sensitive index that can capture the neural characteristics of relative dominance of hedonic and eudaimonic well-being. We recommend that this relative measure should be considered in future neuroimaging, clinical and psychopathological studies, given its capability of integrating two distinctive but related forms of well-being and its high ecological validity.

The present work has several limitations. First, we focused our investigation within DMN due to its fundamental role in EHB. It will be of merit for future work to extend to other networks using advanced analytics such as network analysis. Second, our study demonstrated the correlational relationship between EHB and DMN. Future studies using neural modulation technique to establish the causal relationship are needed. Third, we only compared the neural basis of people with eudaimonic and hedonic dominance. Logically, four categories are possible according to different levels of two forms of well-being: people with high eudaimonic and high hedonic well-being; people with low eudaimonic and high hedonic well-being; people with high eudaimonic and low hedonic well-being; people with low eudaimonic and low hedonic well-being. It will be interesting for future studies to characterize brain functional and structural features of these four well-being subgroups. Fourth, this study performed on a relatively homogenous sample, with the narrow range of age (18–25), the similar education level (undergraduate or graduate) and the same culture (Chinese). Future studies with more diverse sample, such as cross-culture studies, are warranted to generalize the results, given the impact of sociodemographic factors on well-being.

Conclusion

Using both functional and structural MRI techniques, we investigated the neural correlates underlying EHB. Our results highlighted vMPFC and precuneus as neural basis of well-being balance and suggested that enhanced functional connectivity of vMPFC and precuneus was positively correlated with EHB. Furthermore, the left precuneus morphometry was also positively correlated with EHB. These findings provided insights into the associations between EHB and the intrinsic functional and structural architecture of DMN in the brain. This study may provide an avenue for future causal studies with diverse sample.

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Supplementary data

Supplementary data are available at *SCAN* online.

Conflict of interest. None declared.

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