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Neuroanatomical correlates of time perspective: A voxel-based morphometry study

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ABSTRACT

Previous studies indicated that time perspective can affect many behaviors, such as decisions, risk taking, substance abuse and health behaviors. However, very little is known about the neural substrates of time perspective (TP). To address this question, we characterized different dimensions of TP (including the Past, Present, and Future TP) using standardized Zimbardo Time Perspective Inventory (ZTPI), and quantified the gray matter volume using voxel-based morphometry (VBM) method across two independent samples. Our whole-brain analysis (sample 1, N = 150) revealed Past-Negative TP was positively correlated with the GMV of a cluster in LPFC whereas Past-Positive was negatively correlated with the GMV in OFC, and Future TP was negatively correlated with GMV in mPFC. Moreover, two present scales (Present-Hedonistic and Present-Fatalistic TPs) were positively correlated with the GMV of regions in MTG and precuneus, respectively. We further examined the reliability of these correlations between multidimensional TPs and neuroanatomical structures in another independent sample (sample 2, N = 58). Results verified our findings that GMV in LPFC could predict Past-Negative TP while GMV in OFC could predict Past-Positive TP, and the GMV in MTG could predict Present-Hedonistic while the GMV in presuneus could predict Present-Fatalistic, as well as the GMV in mPFC could predict Future TP. Thus, our findings suggest that the existence of selective neural basis underlying TPs, and further provide the stable biomarkers for multidimensional TPs.

1. Introduction

Time offers an important basis for helping us to understand our experiences in the world, including shaping our thoughts, lives, and existence. In fact, the distinction between humans and other animals seems to rely on our ability to travel mentally in time. We can draw on past memories, experience the present, and look forward to future rewards [1]. Personal experiences are parsed or tagged into separable time zones, which was known as time perspective (TP). TP was defined by Zimbardo and Boyd [2] as "… a fundamental dimension in the construction of psychological time, that emerges from cognitive processes partitioning human experience into past, present, and future temporal frames" (P. 1271). Although numerous empirical studies have constructed the conceptual model of TP and further developed a relatively reliable measure for it [3–6], little is known about the multidimensional TPs from neuropsychological perspective. Thus, the exploration basing on neural level is necessary for our further understanding on the TP itself.

Zimbardo and Boyd (1999) clearly proposed that time perspective was the nonconscious processes on the continual flows of personal experiences, and such parallel processing in one's own experience is always divided into time frames for past, present and future [7]. In other words, such "processing" may be treated in a way like personality traits [7,8]. To measure TP, Zimbardo and his colleagues developed the Zimbardo Time Perspective Inventory (ZTPI), which characterizes individual differences towards being Past, Present, or Future orientation. Past TP, which refers to recall of reconstructed past scenarios, generally tends to focus on two dimensions known as "Past-Negative" and "Past-Positive" [7,9]. Past-Negative TP reflects a generally negative, aversive view of the past experience [7]. Previous researches showed that the degree of Past-Negative orientation could predict depression, anxiety and unhappiness [7,10]. Conversely, the Past-Positive TP reflects a warm, sentimental attitude towards the past. Present TP refers to reflect a "Present" attitude towards life and time [7]. According to Zimbardo's time perspective theory, the Present TP also contains two dimensions, namely "Present-Hedonistic" and "Present-Fatalistic". Present-Hedonistic TP reflects a hedonistic, risk-taking and "devil may care" attitude towards time and life. Individuals with higher Present-Hedonistic

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orientation exhibit more impulsivity and less concern for future consequences of their actions [8]. However, Present-Fatalistic TP describes an orientation of hopelessness and helplessness, and the feeling of little control over one's life. Previous studies found that Present-Fatalistic TP generally was related with aggression, depression, and risk seeking [11]. Finally, Future TP is characterized by planning for achievement of future goals. Prior studies suggested that higher Future TP orientation was related to better academic performance [12], better self-directed learning [13], and less impulsive behaviors [14]. Although the ZTPI has been considered to be relatively reliable and valid, the independence of each dimension of the five-factors TP model is still in an ongoing debate [15,16]. Notably, the neuropsychological methods, especially in VBM analysis, can offer a potential possibility to clarify such unclear issues.

Previous studies provided compelling evidences to confirm how TP influence our behaviors [15,17], but little is known about the neural substrates of TP. One functional magnetic resonance imaging (fMRI) study revealed that the medial frontal cortex and frontopolar prefrontal cortex were recruited when participants handle past experience [18]. Meanwhile, this study also demonstrated that present statements recruited specific regions of anterior cingulate cortex and future thinking activated the ventral parts of prefrontal cortex [18]. In addition, some studies on patients found that the individuals with lesion of ventromedial frontal cortex showed a significantly lower level of decision-making towards future frame [19,20]. Although the relationships between some aspects of timing function and their underlying neural substrates have been explored, the neural structural underpinnings of time perspective still remains unclear. Notably, multidimensional TPs that are viewed as stable personality traits may own the corresponding neural substrates. However, the structural basis for each specific time perspective remains unclear to date.

In present study, voxel-based morphometry (VBM) method was conducted to investigate neuroanatomical basis of multidimensional TPs across two independent samples. VBM is a simple and pragmatic approach for characterizing anatomical differences throughout the brain [21]. Importantly, individual differences in diverse cognitive ability and personality can be reliably inferred from neuroanatomical structure [22–24]. Hence, we characterized multidimensional TPs and quantified the gray matter volume across two independent samples. For sample 1, we characterized the different dimensions of TP and identified GMV of brain regions which were significantly correlated with each TP respectively. Then, we conducted a test-validation procedure to ensure the reliability of our findings in another independent sample (sample 2). Specifically, we defined regions of interest (ROIs) based on the findings in sample 1 to test whether GMV in each ROI can predict the corresponding TP.

2. Materials and methods

2.1. Participant and procedure

Sample 1: 150 healthy college students (79 male, 71 female; age, 20.55 ± 1.89) from the Southwest University (China) participated in this study. Eight volunteers were excluded because of either missing data (five subjects) or excessive scanner artifacts (three subjects).

Sample 2: 58 college students (24 male, 34female; age, 19.33 ± 4.01)were recruited from the Southwest University (China).

All subjects gave informed consent, and none had a history of neurological or psychiatric disorder. The experimental protocol was approved by the Institutional Review Board of Southwest University. All the subjects gave written informed consent before the present study. The behavioral measures that were used to characterize individual time perspectives were performed after completing their MRI anatomical scan. After completing these measures, they were paid for their participation.

Table 1
Correlation matrix of Zimbardo Time perspective Inventory terms (n = 150). * $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$.

Factors	1	2	3	4	5
1. Past-Negative	–				
2. Past-Positive	−0.110	–			
3. Present-Hedonistic	0.176*	0.216**	–		
4. Present-Fatalistic	0.451***	−0.033	0.300***	–	
5. Future	−0.153	0.199*	−0.070	−0.245**	–

2.2. Time perspective

In the present study, we conducted Zimbardo Time Perspective Inventory (ZTPI) to measure individuals' TPs. The ZTPI has 56 items that refer to five time orientations: Past-Positive (PP); Past-Negative (PN); Present-Hedonistic (pH); Present-Fatalistic (PF) and Future. Participants rated the extent to which each statement describes them on a 5-point scale from 1 (very uncharacteristic) to 5 (very characteristic). For instance, an item of subscale PP is "It gives me pleasure to think about my past." An item measuring "Future" was "I believe that a person's day should be planned ahead each morning". We calculated each time perspective scores separately by averaging responses to each item. Previous studies have demonstrated that the ZTPI has shown satisfactory reliability and validity in the Chinese setting [25,26]. In this sample, the factors of ZTPI existed significant intercorrelations (see Table 1), which was consistent with previous studies [7,27]. Correlation results showed that PN was positively correlated with pH and PF; PP was positively correlated with pH and Future; pH was positively correlated with PF; PF was negatively correlated with Future.

2.3. MRI structural acquisition

Anatomical images were acquired with a Siemens 3T scanner (Siemens Magnetom Trio TIM, Erlangen, Germany). A circularly polarized head coil was used, with foam padding to restrict head motion. High-resolution T1-weighted anatomical images ($1 \times 1 \times 1.33\ mm^3$) were acquired with an MPRAGE pulse sequence (128 slices; TR = 2530 ms; TE = 3.39 ms; flip angle = 7°; 256 × 256 matrix).

2.4. Preprocessing

All VBM analyses were performed using SPM12 (http://www.fil.ion.ucl.ac.uk/spm). Each MR image was displayed in SPM12 to check for artifacts and gross anatomical abnormalities before starting VBM analysis. The next processing steps were performed exactly as suggested by Ashburner [28]. In short, the anatomic images were first manually reoriented so that the coordinate of the anterior commissure matched the origin (0, 0, 0), and the orientation approximated MNI space. Next, structural MR images were classified into grey matter, white matter (WM) and cerebrospinal fluid (CSF) using the SPM12 new-segment tool, which provides the native space versions and DARTEL imported versions of the tissues. The DARTEL imported versions of grey and white matter were used to generate the flow fields and a series of template images. Afterward, the flow fields and the final template image were then used to create smoothed (8 mm Gaussian FWHM), modulated, spatially normalized, and Jacobian scaled GM images resliced to 2 × 2 × 2 mm voxel size in MNI space.

2.5. VBM analysis

To examine neuroanatomical correlates of time perspective, multiple regression analyses were performed. We constructed five separate GLMs for investigating the neuroanatomical correlates of each separate TPs. In each model, one of the ZTPI factors was included in the design matrix as covariate of interest, while age, gender, GMV of whole-brain