Neuropsychologia 102 (2017) 229–236

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

The effect of future time perspective on delay discounting is mediated by the gray matter volume of vmPFC

Yiqun Guo[a,1], Zhiyi Chen[a,1], Tingyong Feng[a,b,*]

[a] Research center of Psychology and Social development, Faculty of Psychology, Southwest University, Chongqing, China
[b] Key Laboratory of Cognition and Personality, Ministry of Education, China

ARTICLE INFO

Keywords:
Time perspective
Future TP
Delay discounting
VBM

ABSTRACT

Although several previous studies have shown that individuals' attitude towards time could affect their intertemporal preference, little is known about the neural basis of the relation between time perspective (TP) and delay discounting. In the present study, we quantified the gray matter (GM) cortical volume using voxel-based morphometry (VBM) methods to investigate the effect of TP on delay discounting (DD) across two independent samples. For group 1 (102 healthy college students; 46 male; 20.40 ± 1.87 years), behavioral results showed that only Future TP was a significant predictor of DD, and higher scores on Future TP were related to lower discounting rates. Whole-brain analysis revealed that steeper discounting correlated with greater GM volume in the ventromedial prefrontal cortex (vmPFC) and ventral part of posterior cingulate cortex (vPCC). Also, GM volume of a cluster in the vmPFC was correlated with Future TP. Interestingly, there was an overlapping region in vmPFC that was correlated with both DD and Future TP. Region-of-interest analysis further indicated that the overlapping region of vmPFC played a partially mediating role in the relation between Future TP and DD in the other independent dataset (Group 2, 36 healthy college students; 14 male; 20.18 ± 1.80 years). Taken together, our results provide a new perspective from neural basis for explaining the relation between DD and future TP.

1. Introduction

Time is an inescapable dimension of our daily lives. We remember the past, experience the present, and prospect the future. Time perspective (TP), which is a basic dimension of subjective time, is conceptualized as cognitive and motivational processes that partition human experience into past, present, and future temporal frames (Zimbardo and Boyd, 1999; Zimbardo, 2008). A great deal of studies emphasized the importance of TP in regulating behaviors, such as risk-taking, health behaviors, and substance abuse (Breierwilliford and Bramlett, 1995; Fieulaine and Martinez, 2010; Henson et al., 2006; Zimbardo et al., 1997). However, little is known about the neural basis of the association between TP and delay discounting (DD).

Zimbardo and Boyd (1999) and Zimbardo (2008) proposed that TP is a nonconscious process in which temporal frames play a central role in the relationship between personal and social experiences that help to give order and meaning to everyday life events. When one of the three temporal frames is habitually overused in decision making, it serves as a cognitive temporal bias toward being past, present, or future oriented. This chronical bias can be considered as a temporally stable individual-differences construct that exerts a dynamic influence on many judgements and decisions (Zimbardo and Boyd, 1999). The Zimbardo Time Perspective Inventory (ZTPI) was developed to measure TP across five tendencies, including Past-Positive (PP), Past-Negative (PN), Present-Hedonistic (PH), Present-Fatalistic (PF), and Future. Some studies suggest that the Past orientation has demonstrated little explanatory capability in delay discounting research (Apostolidis et al., 2006; Keough, 1999; Teuscher and Mitchell, 2011). Therefore, we focus on the analysis of Present (Present-Hedonistic and Present-Fatalistic) and Future TP as predictors of DD.

Present-Hedonistic TP refers to a concentration on pleasure, obtaining immediate gratification, and little concern about future consequences of one's actions. People with high Present-Hedonistic TP act impulsively, have a high desire to take risk and have low ego control (Zimbardo and Boyd, 1999; MacKillop et al., 2006). Present-Fatalistic orientation, however, reflects a helpless, hopeless, and fatalistic attitude towards life. This TP correlated positively with depression, aggression, anxiety, while negatively with consideration of future consequences (Zimbardo and Boyd, 1999). Recently, a functional magnetic resonance imaging (fMRI) study found that the Present scales (Present-

* Correspondence to: Faculty of Psychology, Southwest University, No. 2, Tian Sheng RD., Beibei, Chongqing 400715, China.
E-mail address: fengty0@swu.edu.cn (T. Feng).

[1] Yiqun Guo and Zhiyi Chen contributed equally to this work.

http://dx.doi.org/10.1016/j.neuropsychologia.2017.06.021
Received 11 April 2017; Received in revised form 15 June 2017; Accepted 19 June 2017
Available online 21 June 2017
0028-3932/

Hedonistic and Present-Fatalistic) recruited specific region of the anterior cingulate cortex (ACC) (Carelli and Olsson, 2015), which functions as conflict monitoring and inhibitory control (Chen et al., 2009; Mac Donald et al., 2000; Ridderinkhof et al., 2004). Independent of Present TP, Future TP reflects individual's tendency to achieve long-term rewards from rejecting immediate pleasure. Focusing on the future is associated with low impulsivity, low risk-taking (MacKillop et al., 2006), and low aggression (Zimbardo and Boyd, 1999). A neuroimaging study found that the inferior frontal gyrus was activated when participants were thinking the statements from Future TP (Carelli and Olsson, 2015). Furthermore, some studies found that patients with organic damages or lesion of the ventromedial frontal cortex (vmPFC) showed reduced future orientation (Bechara et al., 1999; Bechara et al., 2000). These results suggested that Future TP may recruit a few core regions in the prefrontal cortex. It is worthwhile to note that both Present and Future TPs tend to influence many impulsive decisions, which include intertemporal choice (Apostolidis et al., 2006; Keough, 1999).

Intertemporal choice refers to tradeoff between outcomes that occur at different points in time. A consistent finding regarding intertemporal choice is delay discounting (DD), which is the process of devaluing outcomes that take place in the future (Frederick et al., 2002; Green and Myerson, 2004). It is thought that individual differences in DD are fairly stable (Kirby, 2009; Odum, 2011a, 2011b; Odum, 2011). These preferences have even been considered as an important indicator of impulsivity (Bickel, 2015; Bickel et al., 2014). Recent neuroimaging studies have indicated that DD involves a core brain network: valuation network, which is the neural computation and representation of the subjective values of rewards. A large body of evidence implicates the vmPFC, ventral striatum (VS), and posterior cingulate cortex (PCC) in the representation of the subjective value of rewards in delay discounting (Kable and Glimcher, 2007, 2010; McClure et al., 2004; Peters and Büchel, 2011). In addition, some studies have investigated the neuroanatomical correlates of DD, and indicated that DD was associated with GM volume in some valuation network, such as vmPFC, VS (Cho et al., 2013; Tschernegg et al., 2015), and frontal pole (Wang et al., 2016). These neuroimaging studies suggest that individual differences in delay discounting are linked to differences in the neural sensitivities of valuation network.

Some evidence has suggested that Present TP is positively associated, while Future TP is negatively associated, with DD (Apostolidis et al., 2006; Keough, 1999). Daugherty and Brase (2010) found that DD was positively associated with both the Present-Hedonistic and Present-Fatalistic TP of the ZTPI, while was negatively associated with the Future TP of the ZTPI. Furthermore, a large number of studies have indicated that both steep DD and short Future TP correlated with many problematic behaviors, such as risky behavior, addictive disorders, and poor school performance (Hodgins and Engel, 2002; Krueger et al., 1996; MacKillop et al., 2007; Odum et al., 2000; Reynolds, 2006; Siegman, 1961; Yi et al., 2010; Zimbardo et al., 1997). This shared correlation suggests Future TP may be a stable predictor of DD. However, there are few neuroimaging studies on the relationship between DD and TP. Recently studies have shown that both DD and TP recruit corticostriatal circuitry (van den Bos et al., 2014; van den Bos et al., 2015). Increased structural connection between striatum and lateral prefrontal cortex (lPFC) was associated with lower discounting rates and higher scores on Future TP, whereas connection between striatum and ventromedial prefrontal cortex (vmPFC) was associated with steeper discounting rates and higher scores on Present-Hedonistic TP (van den Bos et al., 2014). Some other studies also suggest that these two variables recruit a few core regions in the prefrontal cortex (Bechara et al., 1999; Bechara et al., 2000; Carelli and Olsson, 2015; Kable and Glimcher, 2007; McClure et al., 2004; Peters, 2011). In the present study, we anticipated that brain regions in prefrontal cortex may be the neural basis of the relation between TP and DD.

Neuroanatomical structure can reflect individual differences in various cognitive processes (Gaser and Schlaug, 2003; Gilaie-Dotan et al., 2013; Gilaiedotan et al., 2011; Kumaran et al., 2007; Song et al., 2011). Here we investigated the neuroanatomical basis of the effect of TP on DD using voxel-based morphometry (VBM) methods across two groups. For group 1, we first tested the relationship between DD and different TPs, and then identified the neural basis of TPs and DD, respectively. We next identified the overlapping regions that correlated with both TPs and DD. Furthermore, region-of-interest (ROI) analysis was used to further examine the reliability of results that found in group 1. We calculated the gray matter (GM) volume of the overlapping regions and conducted mediation analysis to test whether the overlapping region of vmPFC played a mediating role in the relation between TP and DD in group 2.

2. Materials and methods

2.1. Participant and procedure

Group 1. One hundred and fourteen participants from the Southwest University (China) volunteered to participate in the study. Twelve participants were recruited but excluded for further analysis because of either missing data (four participants) or not estimating indifferent points in more than one delayed time point in delay discounting task (eight participants, see details below), leaving one hundred and two into VBM analysis (46 male, 56 female; age, 20.40 ± 1.87).

Group 2. To get an independent sample, forty college students from the Southwest University (China) were recruited. Four were excluded because their indifferent point could not be estimated in more than one delayed time, and remained thirty-six participants (14 male, 22 female; age, 20.18 ± 1.80).

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

2.2. Time perspective

After completed the structural MRI scan, participants were required to complete Zimbardo Time Perspective Inventory (ZTPI) (Zimbardo and Boyd, 1999). This inventory is broadly used as a measure for trait time perspective. The ZTPI has 56 items that refer to five time orientations: Past-Positive (PP); Past-Negative (PN); Present-Hedonistic (PH); Present-Fatalistic (PF); Future. Participants rate on a 5-point scale from 1 (very uncharacteristic) to 5 (very characteristic) the extent to which each statement describes them. For instance, an item measuring “Future” was “I believe that a person's day should be planned ahead each morning”. Because some studies suggest that only Present and Future TPs can influence delay discounting (Apostolidis et al., 2006; Keough, 1999; Teuscher and Mitchell, 2011), we only computed Present-Hedonistic, Present-Fatalistic and Future TP scores separately by averaging responses to each item. Some studies have demonstrated that the ZTPI has shown satisfactory reliability and validity in Chinese samples (Chen et al., 2016; Wang et al., 2015). In the present study, the Cronbach's alpha coefficients were 0.712, 0.704, and 0.717, for the Future, Present-Fatalistic, and Present-Hedonistic TP, respectively.

2.3. Delay discounting task

The procedure of delay discounting task was same to one of our previous study (Guo and Feng, 2015). Participants were required to make a series of hypothetical choices between a fixed immediate reward (sooner smaller, SS) (RMB 20, paid today) and a varied delayed reward (larger later, LL). The LL reward was constructed using one of