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Individual differences in resting-state functional connectivity predict procrastination

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ABSTRACT

Procrastination is to voluntarily delay an intended course of action and is considered an archetypal human failing. A popular hypothesis is that procrastination is representative of self-regulatory failure. Although there is extensive behavioral evidence consistent with the predictions of this theory, there is no neural evidence for it. To test directly the extent to which individual differences in trait procrastination can be related to resting-state functional connectivity (RSFC) between brain regions implicated in self-regulation, we applied resting-state functional magnetic resonance imaging (RS-fMRI) in a group of 77 healthy participants. RSFC 1) between ventral medial prefrontal cortex (VMPFC) and dorsal lateral prefrontal cortex (DLPFC), 2) between dorsal anterior cingulate cortex (dACC) and caudate, and 3) within ventral lateral prefrontal cortex (VLPFC), negatively predicted the severity of procrastination. These results provide direct evidence for the validity of self-regulatory failure account of procrastination, and implicate that trait procrastination is reflected in the intrinsic functional dynamics of neural systems associated with impulse control, performance monitoring, and behavioral inhibition.

1. Introduction

Procrastination is defined typically as an irrational tendency to delay the beginning or completion of tasks (Ferrari, 1993), and is regarded as a personality trait that has cross-temporal and situational stability (Steel, 2007). Extensive empirical work has been done on procrastination, involving its prevalence (Ferrari, O'Callaghan, & Newbegin, 2005), its cognitive, behavioral, and affective correlates, such as high anxiety, depression, and low self-confidence (Beck, Koons, & Milgrim, 2000; Ferrari, 1994; Flett, Blankstein, & Martin, 1995), and its causes and solutions (Orpen, 1998).

Why do people procrastinate? The potential causes include task aversion, uncertainty, and fear of failure (Zarick & Stonebraker, 2009). Given the voluntary delay that characterizes trait procrastination, it is not surprising that several studies suggest a link between procrastination and impulsivity. Procrastinators tend to choose short-term benefits over long-term gains (Tice & Baumeister, 1997; Ferrari & Díaz-Morales, 2007). Some people frequently procrastinate tasks because they are unable to control their desire for short-term pleasurable activities (Ferrari & Emmons, 1995). These studies suggest that procrastinators may lack the ability to ward off temptations and distractions of fun alternatives.

One of the popular beliefs is that people procrastinate out of self-regulatory failure (Steel, 2007). Previous empirical studies have supported this view, revealing that procrastination is inversely related to self-regulation (Milgram, Sroloff, & Rosenbaum, 1988). Subsequent behavior–genetics research established procrastination as an evolutionary by-product of impulsivity, with overlapping genetic influences accounted for all of the genetic influences on both procrastination and impulsivity (Gustavson, Miyake, Hewitt, & Friedman, 2014). In addition, self-control has been found to be one of best predictors of procrastination (Ferrari & Emmons, 1995; Rabin, Fogel, & Nutter-Upham, 2011).

As the research shows, self-regulation difficulties contribute to procrastination. Steel calls procrastination a "prevalent and pernicious form of self-regulatory failure that is not entirely understood" (2007, p.65), and supports this position with a massive meta-analysis where he develops Temporal Motivation Theory (TMT), creating one of the most comprehensive look at the issue to date. The TMT includes four components: expectancy (expressed by self-efficacy), value (expressed by task aversiveness), sensitivity to delay (expressed by distractibility, impulsiveness, and lack of self-control), and delay itself (expressed by the timing of rewards and punishments). Steel also notes that although "TMT provides an excellent description of procrastination, further confirmation would be desirable" (2007, p. 83).

Given the potential role of self-regulatory failure as both a contributor and outcome of procrastination, it is surprising that little attention has been directed toward the neural basis underlying this casual link. Steel (2010) discussed how the interplay between the limbic system and the prefrontal cortex could lead to procrastination (Steel, 2010); however, there is no direct evidence for the brain correlates of procrastination.

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One way to test the self-regulatory failure account of procrastination is to investigate resting-state functional connectivity (RSFC), which requires no task or stimuli. This task-independent approach detects inter-regional correlations among spontaneous low-frequency (<0.1 Hz) fluctuations in the fMRI signal within distinct functional networks (Biswal, Zerrin Yetkin, Haughton, & Hyde, 1995). Group resting-state studies have identified resting-state networks consisting of anatomically separated, but functionally linked brain regions that show a high level of ongoing functional connectivity during rest (Van Den Heuvel & Pol, 2010). Recent studies have suggested a direct link between resting-state functional connectivity patterns and cognitive behavior (Hampson, Driesen, Skudlarski, Gore, & Constable, 2006), cognitive ability (Takeuchi et al., 2012), and personality (Adelstein et al., 2011; Takeuchi et al., 2013). However, no study has directly linked resting state phenomena and trait procrastination.

Here we examine the extent to which inter-individual differences in trait procrastination can be predicted by inter-individual differences in RSFC within self-regulation related regions. Based on the TMT theory and the converging evidence that procrastinators tend to be impulsive and lacking in self-control (Steel, 2007, 2010), brain regions associated with self-regulation were selected as seeds [regions of interest (ROIs)]. Self-regulation includes three main ingredients: clear and consistent standards/goal, self-monitoring, and operation/goal pursuit (Baumeister & Heatherton, 1996). Neurally, self-regulation requires top-down control of brain reward systems by prefrontal cortex (PFC) control regions (Heatherton & Wagner, 2011). The three main areas of PFC particularly important to self-regulatory functioning are ventral medial PFC (VMPFC), lateral PFC, and anterior cingulate cortex (ACC) (Heatherton, 2011). VMPFC is a key brain area for representing the value of nearly all reward-types on a common scale (see Levy and Glimcher (2012) for a meta-analysis review). The right ventrolateral prefrontal cortex (VLPFC) and dorsolateral prefrontal cortex (DLPFC) are regions that are commonly activated when people are exerting various forms of self-control (see Cohen and Lieberman (2010) for a review). Furthermore, evidence suggests that successful self-control in decision-making depends on the interplay between DLPFC and VMPFC (Hare, Camerer, & Rangel, 2009; Hare, Hakimi, & Rangel, 2014; Saraiva & Marshall, 2015; Steinbeis, Haushofer, Fehr, & Singer, 2014). The dorsal ACC is also known to be crucial for self-regulation by monitoring the conflict and the need for cognitive control (Botvinick, Cohen, & Carter, 2004; Shenhav, Botvinick, & Cohen, 2013).

Probing above seeds derived from previous literature (Hare, Malmaud, & Rangel, 2011; Hare et al., 2014; Levy & Wagner, 2011; Pine et al., 2009), the present study aimed to test the self-regulatory failure account by assessing the relation between trait procrastination and RSFC within self-regulation related brain regions. We predicted that the patterns of RSFC within regions implicated in self-regulation would predict the severity of procrastination. Specifically, we expected a reduced connectivity between these PFC areas in severe procrastinators.

2. Method

2.1. Participants

Seventy-seven right-handed healthy adults (36 men and 41 women, mean age 22.23 ± 2.54 years) participated. Exclusion criteria were general contraindications against MRI, consummation of drugs, excessive consummation of alcohol and nicotine, medication affecting the central nervous system, history of neurologic or psychiatric disorders, and pregnancy. All participants gave written informed consent for participation in the study and were informed of their right to discontinue participation at any time. The study was approved by the local ethics committee.

2.2. Measures

2.2.1. Trait procrastination

Scores were obtained on a Chinese translation of the 20-item, 5-point General Procrastination Scale developed by Lay (1986) in a testing session after MRI scan. The Chinese version showed adequate internal consistency reliability ($\alpha = .833$) (Chu, Xiao, & Lin, 2010), and had acceptable reliability with the present sample ($\alpha = .625$). Sample items in the original English version of the scale include "I generally delay before starting on work I have to do" (true-keyed) and "I often have a task finished sooner than necessary" (false-keyed).

2.2.2. Self-control

Scores were obtained on a Chinese version of the 19-item Self-Control Scale (SCS) developed by Tangney, Baumeister, and Boone (2004). The SCS measures dispositional self-regulatory behaviors, which represents the tendency to be disciplined and abrogate impulses. The Chinese version showed adequate internal consistency reliability ($\alpha = .862$) and test–retest reliability ($\alpha = .85$) (Tan & Guo, 2008). The alpha coefficient was good in the present sample ($\alpha = .864$). Example items in the original English version of the scale include "I am good at resisting temptation" (true-keyed) and "sometimes I can't stop myself from doing something, even if I know it is wrong" (false-keyed).

2.3. Data acquisition

Resting state functional MRI scans were collected on a 3.0 GE Discovery MRI-750 scanner. Resting-state functional MRI sequences lasted about 6 min (corresponding to 180 brain volumes). The scanning parameters were as follows: TR = 2000 ms; TE = 30 ms; flip angle = 90°; 43 slices; matrix = 64 × 64; FOV = 220 × 220 mm; slice thickness = 3.2 mm; acquisition voxel size = 3.4 × 3.4 × 3.2 mm. A high-resolution T1-weighted anatomical image was also acquired using a magnetization prepared gradient echo sequence (3D MPRAGE, 176 sagittal slices; TR = 8100 ms; TE = 3.1 ms; T1 = 450; flip angle = 8°; FOV = 250 × 250 mm; slice thickness = 1 mm). During resting state scanning, participants were instructed to just lie quietly in the scanner, keep their eyes closed, and think of nothing in particular and let their mind wander.

2.4. Image preprocessing

Functional MRI data were preprocessed with REST toolbox (www.restfmri.net) (Song et al., 2011) using functions of SPM 8 (www.fil.ion.ucl.ac.uk/spm/software/spm8), comprising the following steps: 1) discarding the first 10 volumes to ameliorate the possible effects of scanner instability, 2) slice timing correction, 3) realignment, 4) co-registering the T1-weighted image to the corresponding mean functional image after realignment, 5) segmentation, 6) spatial normalization, 7) smoothing with a Gaussian kernel of 6 mm full width at half maximum, 8) detrending, 9) regressing out the variance of nuisance covariates: head motion correction as well as the global mean signal, white matter signal and cerebrospinal fluid signal, and 10) filtering ($0.01 < f < 0.1$ Hz).

2.5. Individual seed-based functional connectivity analysis

For seed ROIs, we selected the VMPFC, VLPFC, DLPFC, and dACC, four functionally heterogeneous brain areas known to be involved in self-regulation (Heatherton, 2011). We created spherical seed regions of interest (diameter = 6 mm) centered at each of these coordinates in both the left and right hemispheres: VMPFC [Brodmann's area (BA) 11, MNI coordinates: (−6, 41, −14), (6, 41, −14)] (Hare et al., 2011); VLPFC [BA 45, MNI coordinates: (−48, 28, 18), (48, 28, 18)] (Levy & Wagner, 2011); DLPFC [BA 46, MNI coordinates: (−36, 42, 28), (38, 40, 34)] (Harris, Hare, & Rangel, 2013); dACC [BA 32, MNI coordinates: (−3, 33, 30), (3, 33, 30)] (Pine et al., 2009). Time series were averaged across