NeuroImage 147 (2017) 423–431

Contents lists available at ScienceDirect

NeuroImage

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

Functional connectivity in the resting brain as biological correlate of the Affective Neuroscience Personality Scales

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ARTICLE INFO

Keywords:
ANPS
Functional connectivity
Sadness
Resting state
Amygdala

ABSTRACT

According to Jaak Panksepp's Affective Neuroscience Theory and the derived self-report measure, the *Affective Neuroscience Personality Scales (ANPS)*, differences in the responsiveness of primary emotional systems form the basis of human personality. In order to investigate neuronal correlates of personality, the underlying neuronal circuits of the primary emotional systems were analyzed in the present fMRI-study by associating the ANPS to functional connectivity in the resting brain. N=120 healthy participants were invited for the present study. The results were reinvestigated in an independent, smaller sample of N=52 participants. A seed-based whole brain approach was conducted with seed-regions bilaterally in the basolateral and superficial amygdalae. The selection of seed-regions was based on meta-analytic data on affective processing and the Juelich histological atlas. Multiple regression analyses on the functional connectivity maps revealed associations with the SADNESS-scale in both samples. Functional resting-state connectivity between the left basolateral amygdala and a cluster in the postcentral gyrus, and between the right basolateral amygdala and clusters in the superior parietal lobe and subgyral in the parietal lobe was associated with SADNESS. No other ANPS-scale revealed replicable results. The present findings give first insights into the neuronal basis of the SADNESS-scale of the ANPS and support the idea of underlying neuronal circuits. In combination with previous research on genetic associations of the ANPS functional resting-state connectivity is discussed as a possible endophenotype of personality.

1. Introduction

Human personality has been investigated for many years but we still do not exactly understand its underlying biological mechanisms. One reason for this unsatisfying state is that many prominent personality measures such as the NEO-FFI/NEO-PI-R (Costa and McCrae, 1992) base on a lexical approach lacking a theoretical biological background. This makes it complicated to identify the biological basis of personality. One exception are the Affective Neuroscience Personality Scales (ANPS; Davis et al., 2003; see also Davis and Panksepp, 2011) which base on biological concepts and thus offer an option to derive biological candidates to be studied and link self-reported personality traits to neuronal measures. The ANPS consist of seven dimensions (ANGER, CARE, FEAR, PLAY, SADNESS, SEEK and spirituality) of which the first six base on neuroscientific work (capital letters are used to indicate ANPS-scales and their underlying emotional systems rather than the emotion or the emotional state itself). The ANPS has been conceptualized on the background of Jaak Panksepp's Affective Neuroscience Theory (Panksepp, 1998). It postulates that primary emotional systems, which are innate in all mammalian species and have been conserved homologously across the mammalian brain, form the basis of human personality (see also Montag and Panksepp, in press). They are based on distinct neural and neurochemical circuits that have been explored in rodent and feline model species (Panksepp, 1998, see also Panksepp, 2011). The underlying hypothesis of the development of the ANPS is that humans show different activity levels in these emotional systems which moderate the human's affective experience. According to Davis

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http://dx.doi.org/10.1016/j.neuroimage.2016.11.063
Received 29 August 2016; Accepted 26 November 2016
Available online 27 November 2016
1053-8119/

et al. (2003), the variability in personality should be related to those emotional strengths and weaknesses, thus using the ANPS should enable us to measure the sensitivity of our emotional systems and personality traits respectively. This theoretical framework of the ANPS explains how important and plausible it is to investigate its neural basis by analyzing associations to neurotransmitter systems, neural activity or brain structure.

Neuroscientific work in humans concerning the ANPS has mostly focused on genetic association studies and thus rather supported the neurochemical basis of the personality scales: Felten et al. (2011) demonstrated an association between the SADNESS-scale and gene variations in the dopaminergic system and Montag et al. (2011) found an interaction between gene variations in the serotonergic and oxytocinergic systems on the FEAR- and SADNESS-scales. In contrast, neuroimaging work in support of the ANPS' neuroanatomical or functional basis is scarce. Only Reuter et al. (2009) have used voxel-based morphometry to show that gray matter volume in the left amygdala is associated with the ANGER-scale.

To examine the underlying neural circuits of the ANPS we chose to relate them to functional connectivity in the resting brain using functional Magnetic Resonance Imaging (fMRI). Functional connectivity is useful to indicate the interplay between different brain regions as it is defined as the temporal coherence of neuronal activity of different brain regions (Friston et al., 1993). It can be measured by correlating the blood oxygen level dependent (BOLD) signals of different regions of interest (ROI; Fox and Raichle, 2007). When dispositional differences such as personality traits are investigated, functional connectivity is mostly measured in the resting brain. From a theoretical point of view this specific association between personality and the resting brain is plausible because of their commonalities. Functional resting-state connectivity shows trait-like behavior with temporal stability and interindividual consistency (Damoiseaux et al., 2006; Shehzad et al., 2009). There is evidence that functional resting-state networks correspond to those that are activated by different tasks (Smith et al., 2009). Thus the resting-state seems to represent - just as personality (Allport, 1970) - some kind of readiness activation that enables us to react to ensuing stimuli of a certain class in a consistent manner. Previous research supported these theoretical thoughts: interindividual differences in functional resting-state connectivity have already been associated to various personality traits (Adelstein et al., 2011; Markett et al., 2013; Markett et al., 2016; Passamonti et al., 2015) but not yet to the ANPS although the neuroscientific basis of the ANPS renders this association reasonable.

A common method to explore functional connectivity is the seed-based approach which means that functional connectivity between a seed-region and any other voxel in the brain is analyzed. This method requires a specific hypothesis about the brain region whose connectivity shall be examined because the seed-region has to be specified (Fox and Raichle, 2007). The selection of an appropriate seed-region remains a problem since often a seed-region does not represent a functional unit of the brain and thus signals of different brain regions are merged together. Additionally, the decision to select a seed-region is often accompanied by arbitrariness because it usually bases on single specific previous findings of task-activation studies. Nevertheless, the advantage of this approach is the possibility to develop and test theory-based hypotheses and to interpret the results easily. To counteract the disadvantages of the seed-based approach we developed an approach to select theoretically useful and probably functionally homogenous seed-regions. For this purpose we combined two different strategies: we used a histologically informed structural brain atlas (Juelich histological atlas; Eickhoff et al., 2005, 2006, 2007) to prevent the problem of merging signals of different brain regions. The strength of the atlas is that it gives probabilistic maps based on cytoarchitectural properties of the human brain and it does therefore provide structurally homogenous ROIs which are much more likely to show homogenous and functionally meaningful BOLD signals. Furthermore, we considered the results of a meta-analytic approach (www.neurosynth.org, Yarkoni et al., 2011) to only include brain structures that have been reliably and consistently associated with affective processing. The meta-analytic approach can be used to create a brain map – called reverse inference map – which shows the brain regions that are preferentially associated with a chosen keyword ("affective" in the present study). Brain regions reported in studies that include the keyword in their abstracts are compared to brain regions reported in studies that do not include the keyword in their abstracts. By this means, a map is created which displays those regions that are reported more often in the former than in the latter. Combining these two strategies helps to select plausible brain regions as seed-regions. In the present study we used this new approach to associate the ANPS to functional connectivity of the resting brain and thus to explore the neurobiological basis of personality.

2. Material and methods

2.1. Participants and procedure

Resting-state fMRI data of N=120 healthy participants (females n=79, males n=41), who were all university students majoring in different fields, were collected. One female participant was excluded from data analysis because of insufficient data quality (final sample: age M=22.78, SD=4.95). All subjects gave their informed written consent to participate in the study. They were all free of contra-indications to MRI or any psychiatric or neurological condition as assessed by a short screening questionnaire. Participants took all part in the Bonn Gene Brain Behavior Project (BGBBP). As part of their participation they completed the German version of the ANPS (English version by Davis et al. (2003); German version by Reuter et al., in press).

In order to find support for the robustness of our findings we investigated a second sample. This sample consisted of N=52 healthy participants (females n=44, males n=8), who were all university students majoring in different fields. One female participant was excluded from data analysis because of insufficient data quality (final sample: age M=22.35, SD=4.34). As the participants of the first sample, participants of the second sample underwent imaging and filled in the ANPS as part of their participation in the BGBBP.

2.2. Questionnaire measure

The ANPS measures 7 personality traits: ANGER, CARE, FEAR, PLAY, SADNESS, SEEK and spirituality. It consists of 110 items in total that can be answered on a 4-point Likert scale. The first six dimensions were analyzed in this study. Each of these dimensions is assessed with 14 items and is used to measure the participant's responsiveness of one primary emotional system. ANGER refers to feeling and expressing anger and to get frustrated easily. The CARE-dimension points to nurturance tendencies and liking to care for others. FEAR refers to feelings of anxiety and the tendency to ruminate and have difficulties making decisions. The PLAY-scale was defined as having fun in general and playing social games with physical contact and laughter. SADNESS represents feelings of loneliness and social separation distress. SEEK includes being curious, anticipating new experiences and enjoying to explore (Davis and Panksepp, 2011).

Internal consistencies of the ANPS-scales in our samples are reported in Table 1. The values in both samples are in the range from satisfying to excellent.

2.3. Data acquisition

Resting-state fMRI data were collected in a Siemens Avanto 1.5 T Scanner (Siemens, Erlangen, Germany) in the Life & Brain Center in Bonn. From each participant of the first sample 245 T2*-weighted