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ADULT ATTACHMENT STYLE MODULATES NEURAL RESPONSES IN A MENTALIZING TASK

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Abstract—Adult attachment style (AAS) is a personality trait that affects social cognition. Behavioral data suggest that AAS influences mentalizing proficiency, i.e. the ability to predict and explain people's behavior with reference to mental states, but the neural correlates are unknown. We here tested how the AAS dimensions "avoidance" (AV) and "anxiety" (ANX) modulate neural correlates of mentalizing. We measured brain activation using functional magnetic resonance imaging (fMRI) in 164 healthy subjects during an interactive mentalizing paradigm (Prisoner's Dilemma Game). AAS was assessed with the Relationship Scales Questionnaire, including the subscales AV and ANX. Our task elicited a strong activation of the mentalizing network, including bilateral precuneus, (anterior, middle, and posterior) cingulate cortices, temporal poles, inferior frontal gyri (IFG), temporoparietal junctions, superior medial frontal gyri as well as right medial orbital frontal gyrus, superior temporal gyrus, middle frontal gyrus (MFG), and amygdala. We found that AV is positively and ANX negatively correlated with task-associated neural activity in the right amygdala, MFG, mid-cingulate cortex, and superior parietal lobule, and in bilateral IFG. These data suggest that avoidantly attached adults activate brain areas implicated in emotion regulation and cognitive control to a larger extent than anxiously attached individuals during mentalizing.

Key words: theory-of-mind, attachment, fMRI, social cognition.

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Abbreviations: AAS, adult attachment style; ACC, anterior cingulate cortex; ANX, anxious attachment style; AV, avoidant attachment style; BDI, Beck Depression Inventory; BLA, basolateral nucleus of amygdala; CMA, central-medial amygdala; dACC, dorsal anterior cingulate cortex; dlPFC, dorsolateral prefrontal cortex; dmPFC, dorsomedial prefrontal cortex; fMRI, functional magnetic resonance imaging; IFG, inferior frontal gyri/gyrus; ILFC, inferior lateral frontal cortex; MCC, middle cingulate cortex; MFG, middle frontal gyrus; OFC, orbitofrontal cortex; PDG, Prisoner's Dilemma Game; SPL, superior parietal lobule; STAI-T, State-Trait Anxiety Inventory, Trait; TPs, temporal poles; vmPFC, ventromedial prefrontal cortex.

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INTRODUCTION

"Avoidance" (AV) and "anxiety" (ANX) are important dimensions of the adult attachment style (AAS; Mikulincer and Shaver, 2007), which is relevant for social behavior and cognition. That individual differences in AAS are related to neural correlates of mentalizing is likely, but has not been tested so far. With this study we investigated whether AV and ANX are associated with distinct activations in a mentalizing-related neural network.

An important framework for the understanding of human social-cognitive development is offered by attachment theory. It proposes that humans have an innate motivation to form an emotional bond with another person (attachment figure) and that its evolutionary function is to give protection and care for one's child (Bowlby, 1969). In a social constructionist view the function of attachment may go far beyond providing physical protection to the child. Attachment is assumed to foster social cognition and thereby to prepare the developing child for cooperation with others (Fonagy et al., 2007).

Caregivers differ in the way they respond to the proximity-seeking behavior of the child and thereby shape its attachment behavior. The adaptation to repeated contacts leads to cognitive-affective structures (internal working models) on the availability and security-providing features of the attachment figure. Thereby the individual attachment style evolves over time into an individual trait that remains moderately stable into adulthood (Fraley, 2002) and affects social cognition and behavior (Mikulincer and Shaver, 2007). The individual attachment style is "activated" not only in close relationships, but also toward unfamiliar others (to avoid confusion with "brain activation" in the remainder of the text we replace "activate" with "trigger" and "deactivate" with "disable" when referring to the attachment system) (Fraley et al., 2006; Vrtička et al., 2008, 2012). A secure attachment style is developed in a history of responsive and trustful interaction experiences. Attachment figure unavailability however leads to insecure attachment and forces a person to use a "secondary attachment strategy" (Mikulincer and Shaver, 2007). At least two different dimensions of attachment style exist that are termed "avoidance" (AV) and "anxiety" (ANX). In adulthood AV and ANX can be reliably assessed by two-dimensional self-report measures, conceptualized as two orthogonal axes (Simpson et al., 1992; Kurdek, 2002; Mikulincer and Shaver, 2007).

An avoidant attachment style (AV) is characterized by disabling strategies such as maintaining of self-reliance and distance, and by avoiding emotional states that might trigger the attachment system. Inhibited attention to emotions of oneself and others, down-regulated emotions, and blocked emotional reactions are typical for AV, as well as enhanced attention to environmental objects and predominance of cognitive information processing (Crittenden, 1995; Mikulincer and Shaver, 2007). By contrast, an anxious attachment style (ANX) is characterized by exaggerated proximity-seeking, heightened access and attention to threat-related memories and thoughts, and a predominance of affective communication (Crittenden, 1995; Mikulincer and Shaver, 2007). Thus, the individual attachment styles represent important personality dimensions which affect social-cognitive and behavioral processes in social situations.

Few neuroimaging studies investigated neural correlates of AAS by means of affective and/or attachment-related stimuli. In avoidantly attached individuals the dorsal anterior cingulate cortex (dACC) and insula were less activated following the experience of social exclusion vs. social inclusion in a virtual ball-tossing game (DeWall et al., 2012). Positive feedback provided by pictures of happy facial expressions in a pseudogame context resulted in less activation of reward-related areas (ventral striatum, ventral tegmental area) in avoidantly attached subjects (Vrtička et al., 2008). Activation of somatosensory cortices was negatively correlated with AV during processing of sad facial expressions (Suslow et al., 2009). These data support the view that the strategy of withdrawal renders avoidant individuals less sensitive to social rejection, negative interpersonal signals, and to social reward. However in response to pictures of unpleasant social scenes and facial signals implying social conflict AV was positively associated with recruitment of brain areas related to cognitive control as well as cognitive and emotional conflict (dACC, ventral ACC), and emotion regulation (dorsolateral prefrontal cortex) (Vrtička et al., 2012). In response to pictures of pleasant social scenes AV was positively correlated with brain activity in regions implicated in motor inhibition and valuation (supplemental motor area, medial orbitofrontal cortex) (Vrtička et al., 2012). During negative thought suppression avoidantly attached individuals displayed higher activation of the ventral anterior cingulate cortex and lateral prefrontal cortex which was interpreted as less efficient suppression of negative thoughts (Gillath et al., 2005). Altogether these data suggest that AV modulates activation of brain areas implicated in pain, conflict and reward processing, and emotion regulation (e.g. dACC, insula, lateral prefrontal cortex, and ventral striatum) during the processing of emotionally significant cues.

ANX was shown to be associated with greater neural activations in dACC in response to experience of social rejection and during thinking about negative relationship scenarios (Gillath et al., 2005; DeWall et al., 2012). Negative feedback provided by angry faces and pictures of unpleasant social scenes elicited higher activation of amygdala in anxiously attached individuals (Vrtička et al., 2008, 2012). However facial cues depicting sadness did not evoke ANX-associated neural activations (Donges et al., 2012). Anxiously attached individuals further recruited several brain areas implicated in emotion processing and memory to a higher extent when they were confronted with social rejection experience, happy facial expressions, and pictures of pleasant or unpleasant social scenarios (DeWall et al., 2012; Donges et al., 2012; Vrtička et al., 2012). They activated brain areas implicated in emotion regulation (orbitofrontal cortex) to a lower extent when thinking about negative relationship scenarios (Gillath et al., 2005). In sum, the results in anxiously attached individuals show differential activation in the dACC, amygdala, and hippocampus (among others) which were interpreted as heightened vigilance, salience, and memory for emotionally significant social cues.

These previous neuroimaging studies focused on automatic brain reactivity to facial expressions, thought suppression, emotion processing, and response to social exclusion vs. inclusion. To our knowledge, the effect of AAS on the neural correlates of mentalizing has not been addressed so far. However, behavioral data have shown links between attachment quality and mentalizing ability (see below).

Mentalizing, also called theory-of-mind, is defined by "imputing mental states to oneself and others" (Premack and Woodruff, 1978) and provides "the ability to predict and explain people's behavior with reference to mental states" (Repacholi and Slaughter, 2003). Mentalizing ability is regarded as fundamental for successful human social interactions and is typically impaired in severe mental disorders like autism (Baron-Cohen et al., 1985) and schizophrenia (Biedermann et al., 2012).

Mentalizing is regarded as a multidimensional construct and likely comprises distinct cognitive processes and cerebral networks (Frith and Frith, 2001; Hynes et al., 2006; Fonagy and Luyten, 2009). Most commonly a distinction between cognitive and affective mentalizing is made with respect to the content of mentalizing that can be either knowledge and beliefs or emotions and intentions (Brothers and Ring, 1992; Fonagy and Luyten, 2009; Abu-Akel and Shamay-Tsoory, 2011). A mentalizing-related neural network has been identified (Mar, 2011), that consists of the bilateral medial prefrontal cortices, temporoparietal junctions, superior temporal sulci, temporal poles (TPs), anterior temporal lobes, posterior cingulate cortices, precuneus, inferior frontal gyrus, and possibly the amygdala (of the right hemisphere in nonstory-based studies). Neural cognitive and affective execution loops for the processing of affective and cognitive mental states have been put forward by Abu-Akel and Shamay-Tsoory (2011). The cognitive mentalizing network is suggested to involve the dorsal parts of lateral (dlPFC) and medial prefrontal cortex (dmPFC), anterior cingulate cortex (ACC), TP, and striatum. The affective mentalizing network is assumed to engage the amygdala, inferior lateral frontal cortex (ILFC), orbitofrontal cortex (OFC), and the ventromedial prefrontal cortex (vmPFC), ACC, TP, and striatum (Abu-Akel and Shamay-Tsoory, 2011).

Different approaches have been employed to investigate the neural correlates of mentalizing, categorized in story- and nonstory-based studies (Mar, 2011). Story-based designs have been criticized to be