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Amygdala Functional and Structural Connectivity Predicts Individual Risk Tolerance

Highlights

- Neural markers for risk tolerance were investigated with multimodal imaging data
- Risk tolerance correlated with amygdala-medial prefrontal cortex connectivity
- Risk tolerance correlated with amygdala structure

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In Brief

Jung et al. examine neural markers for risk tolerance in a large multimodal imaging dataset of young adults. Higher risk tolerance was associated with amygdala structure and function and with structural and functional connectivity between amygdala and medial prefrontal cortex.

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Amygdala Functional and Structural Connectivity Predicts Individual Risk Tolerance

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SUMMARY

Risk tolerance, the degree to which an individual is willing to tolerate risk in order to achieve a greater expected return, influences a variety of financial choices and health behaviors. Here we identify intrinsic neural markers for risk tolerance in a large (n = 108) multimodal imaging dataset of healthy young adults, which includes anatomical and resting-state functional MRI and diffusion tensor imaging. Using a data-driven approach, we found that higher risk tolerance was most strongly associated with greater global functional connectivity (node strength) of and greater gray matter volume in bilateral amygdala. Further, risk tolerance was positively associated with functional connectivity between amygdala and medial prefrontal cortex and negatively associated with structural connectivity between these regions. These findings show how the intrinsic functional and structural architecture of the amygdala, and amygdala-medial prefrontal pathways, which have previously been implicated in anxiety, are linked to individual differences in risk tolerance during economic decision making.

INTRODUCTION

To make adaptive choices, decision makers must integrate their beliefs about the possible outcomes of each action with their evaluation of those possible outcomes. However, one challenge that decision makers confront is that there is often uncertainty about what outcomes will result from a given action. A particular form of uncertainty, when information about the probability of each possible outcome is known, is referred to as "risk" (von Neumann and Morgenstern, 1994). Examples of risk include the outcomes of a fair coin toss, die roll, or roulette wheel. An individual's risk tolerance (also referred to as "risk attitude" or "risk preference"), their willingness to accept risk in order to gain a greater expected return, can be measured by assessing preferences between small-but-certain and larger-but-risky rewards (Glimcher, 2008; Levy et al., 2010; Gilaie-Dotan et al., 2014). Understanding individual differences in risk tolerance is important, because risk tolerances are not only associated with financial decisions (e.g., investments, insurance) but also with smoking (Lejuez et al., 2003, 2005; Schepis et al., 2011), health behaviors (Anderson and Mellor, 2008), migration (Barsky et al., 1997; Dohmen et al., 2005), self-employment status (Ekelund et al., 2005), susceptibility to mental illness (Branas-Garza et al., 2007; Krain et al., 2008), and patients' attitude to treatment (Fraenkel et al., 2003; Barfoed et al., 2016). Here we examined neural predictors of individual differences in risk tolerance using a multimodal neuroimaging approach.

Over the past decade, functional neuroimaging studies have identified multiple brain regions engaged when making decisions involving risk (Mohr et al., 2010; Knutson and Huettel, 2015). Activity in the parietal cortex reflects the probability of outcomes (Huettel et al., 2006; Studer et al., 2015); activity in medial prefrontal cortex (mPFC) and the ventral striatum (i.e., nucleus accumbens [NAcc]) reflects an integration of the magnitude and probability of rewards for given risky options (Ernst et al., 2004; Krain et al., 2008; Levy et al., 2010); and activity in the anterior insula (aINS), anterior cingulate cortex (ACC), and amygdala reflect the degree of risk or uncertainty (Kuhnen and Knutson, 2005; Preuschoff et al., 2008; De Martino et al., 2010). Furthermore, neural activity, particularly in the NAcc, mPFC, and aINS, predicts the choice that the individual will make (Kuhnen and Knutson, 2005; Huang et al., 2014; Leong et al., 2016).

There is recent interest, though, in moving beyond predicting choice from simultaneously measured task-evoked brain activation, toward predicting behavior at greater remove, by testing whether task-independent measures of brain structure and function, from anatomical or resting-state functional MRI (RS-fMRI) or diffusion-tensor imaging (DTI), can predict decision-making tendencies (Fumagalli, 2014; Kable and Levy, 2015). For instance, increased gray matter volume (GMV) in the right posterior parietal cortex (rPPC) is associated with increased risk tolerance (Gilaie-Dotan et al., 2014; Grubb et al., 2016). Examining multiple neuroimaging modalities together, however, may provide an even better understanding of the complex interplay among brain structure and function and behavior. In a recent example, the preference for positively skewed gambles (lotteries that yield large amounts with small chances) was associated with the coherence (fractional anisotropy [FA]) of the white matter (WM) tract connecting aINS and NAcc (Leong et al., 2016), and activity in the NAcc during choice mediated the link between tract structure and choice behavior. To our knowledge, there have been no similar multimodal imaging investigations of

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