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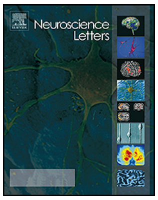

Research paper

Loss aversion is associated with bilateral insula volume. A voxel based morphometry study

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HIGHLIGHTS

- Loss aversion is a decision-making bias.
- We use voxel-based morphometry to study individual differences in loss aversion.
- Loss aversion was quantified using a behavioral assay involving economic decisions.
- Higher loss aversion was associated with reduced volumes of bilateral insulae.
- Results are in line with a "salience network" that centers around the insula.

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ABSTRACT

Loss aversion is a decision bias, reflecting a greater sensitivity to losses than to gains in a decision situation. Recent neuroscientific research has shown that mesocorticolimbic structures like ventromedial prefrontal cortex and the ventral striatum constitute a bidirectional neural system that processes gains and losses and exhibits a neural basis of loss aversion. On a functional and structural level, the amygdala and insula also seem to play an important role in the processing of loss averse behavior. By applying voxel-based morphometry to structural brain images in N = 41 healthy participants, the current study provides further evidence for the relationship of brain structure and loss aversion. The results show a negative correlation of gray matter volume in bilateral posterior insula as well as left medial frontal gyrus with individual loss aversion. Hence, higher loss aversion is associated with lower gray matter volume in these brain areas. Both structures have been discussed to play important roles in the brain's salience network, where the posterior insula is involved in interoception and the detection of salience. The medial frontal gyrus might impact decision making through its dense connections with the anterior cingulate cortex. A possible explanation for the present finding is that structural differences in these regions alter the processing of losses and salience, possibly biasing decision making towards avoidance of negative outcomes.

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1. Introduction

Everyday decisions often involve cost-benefit calculations, which require an anticipation of prospective gains and losses. According to prospect theory [1,2] this calculation is largely affected by emotional processes and heuristics. One prominent example is the phenomenon of loss aversion. It refers to a greater sensitivity to losses than equivalent gains in a decision situation [3]. Many studies report an average loss aversion of 2, representing a double weighting of losses compared to gains, which means that most people would accept a 50:50 gamble (e.g. tossing a coin) only when the gain is at least twice the amount of the possible loss. Even though some studies have reported a lower loss aversion value or even present experimental conditions under which loss aversion disappears [4,5], there is broad consensus that prospective losses receive greater weights than gains in decision making.

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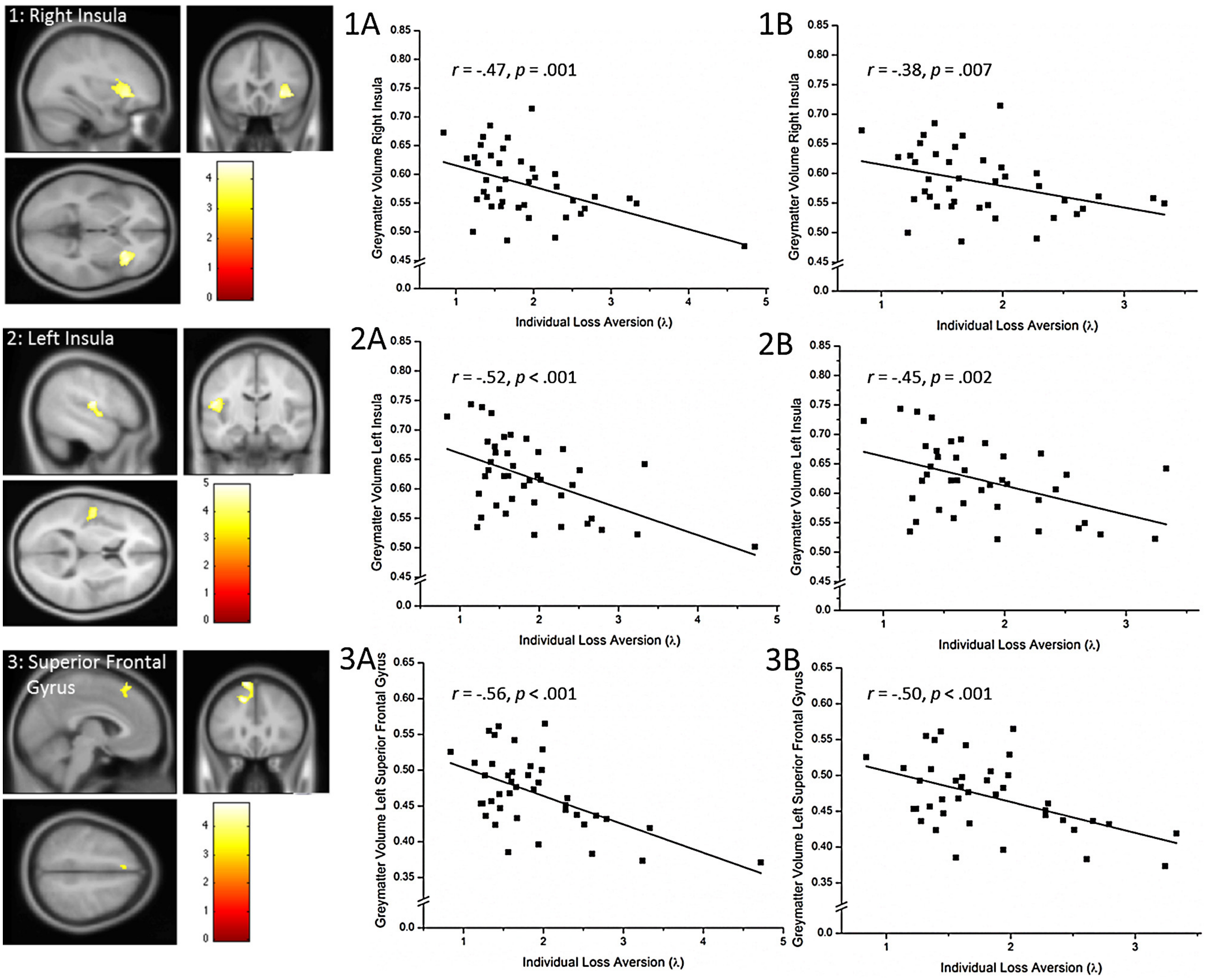

Fig. 1. Whole-brain statistical parametric maps and corresponding scatterplots including (A) and excluding (B) an outlier, showing the association of behavioral loss aversion and gray matter volume, thresholded at $p < 0.05$ (FWE on cluster level). Multiple regression revealed three clusters with negative associations of gray matter volume and loss aversion: 1) in the right insula ($k = 1142$, peak MNI coordinate: 28, 21, 0), 2) in the left insula ($k = 831$, peak MNI coordinate: −51, −12, 16) and 3) in the left superior frontal gyrus ($k = 684$, MNI coordinate: −16, 29, 43).

The neurobiological basis underlying this decision bias has been investigated, but there is still no consistent view on a neural system behind loss aversion. In a functional magnetic resonance imaging (MRI) study, Tom et al. [6] found that activation of the ventromedial prefrontal cortex (VMPFC) and the ventral striatum is associated with both, losses and gains, and represents a bidirectional processing of gains and losses within the same neural system. The authors report that both structures mediate a neural loss aversion, evident in a steeper degree of deactivation in response to losses versus activation in response to equivalent gains in these regions. This neural loss aversion was reported to correlate with behavioral loss aversion. The study reported no activation specific to losses in regions often associated with affective processing like amygdala or insula. DeMartino et al. [7] on the other hand showed an elimination of loss aversion in patients with amygdala lesions, and Sokol-Hessner et al. [5] reported a reduction of both, loss aversion and amygdala response to losses, by the use of emotion regulation strategies. In an attempt to integrate these inconsistent results, Canessa et al. [8] replicated the findings of the bidirectional processing of gains and losses in a mesocorticolimbic system that possibly evaluates stimuli regarding their reward value. The authors also reported loss specific activation in a system including amygdala and posterior insula in the absence of gain-related deactivations, which seemed to reflect an anticipation of negative outcomes. These results provide support for the hypothesis that mesocorticolimbic structures as well as the insula and amygdala play an important role in the processing of loss aversion. Additionally, on a structural level, Canessa et al. [8] reported that gray matter volume in the amygdala and posterior insula were positively correlated with behavioral loss aversion.

Nevertheless, the question of the neural system underlying loss averse behavior as well as individual differences in decision making needs further empirical evidence. Especially the role of regions that have been shown to be involved in affective processing like amygdala and insula remain to be further investigated. Given the high relevance of this question for decision making research, the present study seeks to provide additional structural MRI data to assess the relationship of brain structure and loss aversion behavior using voxel-based morphometry (VBM).

2. Method

2.1. Participants

We initially recruited N = 46 healthy participants for a study on the neural correlates of loss aversion ($n = 41$ females, $n = 5$ males,

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