Neural substrates and behavioral

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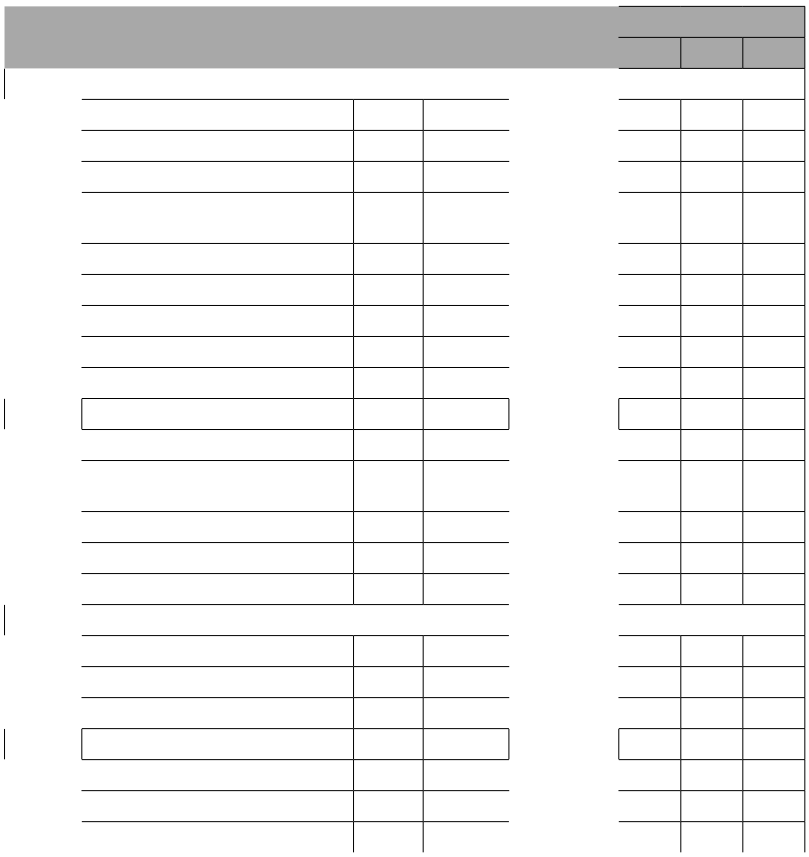
Jealousy is a fundamental social emotion composed of affective, cognitive, and behavioral components

[1]. Although jealousy in general could be the result of many different kinds of social comparisons (i.e., social status, wealth, and achievement), romantic jealousy is the most prevalent and important form, as romantic love is a universal human phenomenon and is related to reproduction[2]. Appropriate jealousy, indicating the intention to protect the relationship, is essential for experiencing love and maintaining romantic relationship stability[3]. However, when jealousy goes to the extreme, it can confer tremendous economic and psychological costs on individuals and society, leading to aggressive behaviors such as domestic violence, suicides, and murders[4,5]. Romantic jealousy is connected with several psychoses such as substance abuse and affective disorders[6,7]. To date, however, we know little about the neural correlates of romantic jealousy.

The affective and experiential core of romantic jealousy is a mixture of some basic emotions, such as anger, sadness and surprise, which arises from a relationship-threatening event[8,9]. According to the appraisal theory[10], emotion, especially complex social emotions, depends on the cognitive apprehension of the antecedents of the emotion. In the case of romantic jealousy, one of the most important antecedents is how one perceives his/her relationship: how one cares for the relationship and what one expects from it[8]. Drawing on a recent theoretical framework that treats social emotion (e.g., guilt, anger) as violation of goal[11], we envision romantic jealousy as a violation of what one expects from a romantic relationship and the romantic partner (e.g., loyal to each other, the goal of living together, etc.). Such expectancy may be reflected in romantic happiness, as those who are happier in their romantic relationship is less likely to believe that their relationship could be affected by a romantic

rival. It is thus conceivable that when facing the same relationship-threatening event, those who are happier in their relationship will nd it more surprising and unacceptable, and will feel more jealousy. is is a testable hypothesis (Hypothesis 1) to be addressed in this study.

Romantic happiness and jealousy unfold in time. Being engaged in a formal romantic relationship can change romantic jealousy from the initial desire to obtain what one does not have to the fear of losing what one already has[4,12]. In a more ne-grained psychological conception, these two stages of jealousy involve similar but not identical feelings[13]



We found stage di erences for romantic jealousy in both the behavior and brain activation patterns. A er engaging in a formal romantic relationship, individuals may have increased expectancy for loyalty and closeness rendering the violations more salient when threats occur. In line with this postulate, relative to the rst stage, the self-reported intensity of romantic jealousy and the jealousy-related activations in GP and VS increased in Stage 2 Speci cally, the stage changes were re ected in the decrease of jealousy in control conditions from Stage 1 to Stage (Figs 3a and 6b,c). is suggests that being engaged in a formal relationship narrows down romantic concern to the relationship partner, which may demonstrate the neural basis of human monogamy.

e increased romantic jealousy a er establishing the formal romantic relationship correlated with a higher possibility of interpersonal aggression. According to a population-based survey in China in ref. 25, 7.2% of women aged between 20 and 49 reported that they su ered from partner violence in the past year and that

Figure 4. e romantic jealousy-related brain activations. e main e ect of romantic jealousy (Partner> Control) produced activations in the basal ganglia, thalamus, middle cingulate, and others.

Figure 5. e romantic happiness-related brain activations. Romantic happiness (Partner Control) produced activations in the medial prefrontal cortex and the posterior midline structures.

jealousy was a vital source of this risk[26]

In the rst-level (within-participant) analysis, we de ned a factorial model and a parametric model. Our data analysis focused on the emotion-evoked period. For the factorial analysis, we modeled the emotion-evoked period (11s) using four regressors, each corresponding to one experimental condition. An additional regressor was used to model the response period. For the parametric analysis, all scenario-reading events correspondin to the jealousy content (i.e., scenarios of the jealousy-partner and jealousy-control conditions in both Stages) were combined into a single regressor. e jealousy rating of each trial was added to this regressor as a rst-order parametric modulation. Similarly, all scenario-reading events corresponding to the happiness content (i.e., scenarios of the happiness-partner and happiness-control conditions in both Stages) were combined into a single regressor, with the happiness rating as the rst-order parametric modulation. For both the factorial and the parametric analysis, events were modeled with boxcar regressors (duration 11s) convolved with standard hemodynamic response function (HRF). e six rigid body parameters were included to account for head motion artifacts. Based on these rst level analyses, we carried out the second (group) level analyses both within predened regions-of-interest and on the whole-brain. For the ROI analysis, we extracted the parameter estimates (beta value) around the coordinates reported in previous studies on jealousy (le GP, $x=-12, y=2, z=2$[21], le VS, $x=-7, y=12, z=-4$[20], and le vmPFC, $x=-3, y=44, z=-15$[36]). Parameter estimates were extracted from a cube (each side length of the cube was 3 voxels) containing 27 voxels around these coordinates and subject a 2 Stages (before vs. a er being in a formal relationship) by 2 Targets (Partner vs. Control) repeated-measure ANOVA, which separately did for happiness and jealousy. At the whole-brain level, the factorial analysis and the parametric analysis were carried out separately. For the factorial analysis of each emotion, the four individual contrast maps corresponding to the presentation of scenarios were fed into a exible-factorial matrix, i.e., "Partner_Before", "Control_Before", "Partner_A er", and "Control_A er". We de ned 2 sets of contrasts: (1) the

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