The amygdalostriatal and corticostriatal effective connectivity in anticipation and evaluation of facial attractiveness

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2011; Schultz, 1998). The vmPFC and the adjacent parts of the medial orbitofrontal cortex (mOFC) are consistently implicated in representing abstract value of choices and outcomes (FitzGerald, Seymour, & Dolan, 2009; Kim, Shimojo, & O'Doherty, 2010; Knutson, Fong, Adams, Varner, & Hommer, 2001; Knutson, Fong, Bennett, Adams, & Homme, 2003; O'Doherty, Kringelbach, Rolls, Hornak, & Andrews, 2001; for reviews, see Kringelbach, 2005; O'Doherty, 2004; Schoenbaum, Roesch, Stalnaker, & Takahashi, 2009).

The vmPFC and VS are structurally and functionally connected. Anatomical studies on non-human primates showed that tracers injected in the vmPFC labeled the fibers that terminate in the nucleus accumbens (NAcc), a limited area within the VS (Haber, Kunishio, Mizobuchi, & Lynd-Balta, 1995). Instead of directly innervating the prefrontal cortex, the efferent projections from VS primarily target the pallidum and midbrain. The latter structures in turn project back to the prefrontal cortex, including the vmPFC (Hedreen & DeLong, 1991). Neuroimaging techniques, such as the diffusion tensor imaging (DTI) and resting state MRI, have also demonstrated the frontostriatal structural connectivity in humans (Cauda et al., 2011; Di Martino et al., 2008). Functionally, studies on drug addiction provide evidence for the interplay between the vmPFC and the VS (Goldstein & Volkow, 2002; Kalivas & Volkow, 2005), suggesting that the prefrontal-to-NAcc glutamate projection may substantiate the transmission from the value of the reinforcer keu-227.7(2002;)-231(Kalithe)-273.7(2002wc[e4(value)-228(o3202.2-1.30883sionn5niectivity87tru influence of the blurred faces on the perceptual processing of the subsequent feedback faces as well as to make sure that about half of the trials would constitute ‘‘correct’’ trials.

2.3. Procedures

Stimuli were presented at a viewing distance of about 60 cm through an LCD projector onto a rear projection screen located behind the participant’s head. Participants viewed the screen through an angled mirror on the head-coil. The task was administered using Presentation software (http://nbs.neuro-bs.com/) to control the presentation and timing of stimuli.

A similar experiment procedure was adopted here as in our previous study (Zhang, Li, Qian, & Zhou, 2012). At the start of each trial, a white fixation cross was presented for 250 ms against a black screen. Next, one of the ten blurred photos was presented for 2000 ms at the center of the screen, during which the participant made a guess as to whether the blurred face was attractive or unattractive by pressing a button with the right index or ring finger. The mapping between responses and fingers was counterbalanced across participants. The participant was told to press the button as soon as possible, and if the response was made after the six critical regressors for each participant. The six first-level individual contrast images were then fed into a flexible factorial test across participants in the second-level design matrix.

Contrasts corresponding to anticipation and the outcome evaluation were defined: ‘‘Guess_Attractive > Guess_Unattractive’’, ‘‘Attractive_Outcome > Unattractive_Outcome’’, ‘‘Congruent_Outcome > Incongruent_Outcome’’, and the reversed contrasts of the above ones. Statistical analyses were conducted both at the whole-brain and predefined region of interest (ROI). For the whole-brain analysis, clusters that survived $p < 0.001$ (uncorrected) at peak voxel level and p (FWE) < 0.05 at cluster level were reported (Table 1). A priori ROI activations were tested for significance by using small-volume correction (SVC) within a 10 mm-radius sphere with a peak threshold of p (FWE) < 0.05 and an extent threshold of 100 mm^3 (≈12 voxels). Beta estimates corresponding ‘‘unattractive’’ guesses (M = 82, SD = 18; $t(17) = 3.13$, $p < 0.01$, two tailed). A post-experiment test showed that participants all agreed with the facial attractiveness categorization of the unblurred faces derived from the pretest. At the feedback stage, the distribution of trials for the four conditions was as follows: attractive-congruent, 26.7%, attractive-incongruent, 21.8%, unattractive-congruent, 21.0%, and unattractive-incongruent, 27.7%.

3.2. Neuroimaging results

3.2.1. Neural activations related to anticipation and outcome evaluation

The ‘‘Guess_Attractive > Guess_Unattractive’’ revealed activation in the right amygdala and right VS (Table 1 and Fig. 2). The left amygdala and the left VS activation clusters were also observed at a relatively liberal threshold ($p < 0.001$ uncorrected at peak voxel level and contained more than 100 voxels). The reversed contrast did not reveal any significant clusters.

At the outcome evaluation stage, congruent feedbacks activated the left VS and the left inferior parietal lobule compared with incongruent feedbacks (Table 1 and Fig. 3A and B). The reversed contrast did not reveal anything significant. On the other hand, compared with the unattractive feedback faces, the attractive feedback faces activated bilateral FG and IOG (Fig. 3C). Again, the reof attractive faces ($t(17) = -2.27$, $p < 0.05$). Second, the intrinsic connectivity from the amygdala to the VS was significantly larger than 0 ($t(17) = 3.01$, $p < 0.01$) and also larger than the intrinsic connectivity from the VS to the amygdala ($t(17) = 3.00$, $p < 0.01$). Third, although the modulatory effects of ‘‘Guess_Attractive’’ (0.11 ± 0.24; $t(17) = 1.91$, $p = 0.07$ uncorrected) and ‘‘Guess_Unattractive’’ (0.03 ± 0.07; $t(17) = 2.07$, $p = 0.05$ uncorrected) on the amygdala-to-VS intrinsic connectivity were marginally significant when tested separately, the combined modulatory effect of these two conditions was significantly larger than zero (0.07 ± 0.14; $t(17) = 2.24$, $p < 0.05$). These results indicated that the choice-related information is first represented in the amygdala and is projected to the vmPFC and that this functional connectivity could be enhanced by the act of choice.

3.3. Functional interplay between VS and vmPFC during outcome evaluation

For the outcome evaluation stage, the model family in which the vmOFC served as information input (Family B) had an exceedance probability (0.98) far greater than vl(((ouat)-4.8(than)-271.8(vl(((ouat)-4.8V1((0.98))-2MCID1>>BDCT/F11Tf38.1853032.768592.2393Tm(as71(0

2005). These studies suggested that the knowledge of "success" in doing something is itself rewarding and can drive the activity in the VS. Taken together, we may argue that whether positive feedbacks, as compared with negative feedbacks, can elicit stronger activity in the VS is highly context-dependent.

The vmPFC is consistently implicated in encoding reward magnitude rather than prediction error (Hare et al., 2008). Our finding