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An event-related fMRI study on risk taking by healthy individuals of high or low impulsiveness

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ABSTRACT

This event-related functional Magnetic Resonance Imaging study examined the differential neural activities associated with a Risky-Gains task in 18 healthy individuals of high ($n = 9$) or low ($n = 9$) impulsiveness, according to their scores on the Barratt Impulsiveness Scale (BIS). The neural activities of people belonging to the high and low impulsiveness groups were monitored by a 3T MRI scanner while they were performing the Risky-Gains task. We demonstrated that a stronger activation in the insula-orbitofrontal-parietal regions was found in the high impulsiveness group compared to the low impulsiveness group. However, the levels of activation in the lateral prefrontal and anterior cingulate regions did not differ between the two groups. The findings suggest that the neural substrates of comprehension of cognitive and affective information associated with risk-taking decision making may vary according to the impulsiveness among healthy individuals.

Risk-taking behaviors are associated with a series of cognitive and affective processes that aim to balance the potential losses and benefits of an action [1]. The failure to appropriately regulate risk-taking behaviors could lead to socially inappropriate acts or even pathological behaviors presented in people with various neuropsychiatric disorders [12,13,18,30,33]. Clinical studies have revealed several brain regions that are involved in risk-taking decision making. Bechara et al. [2] showed that patients with prefrontal lesions failed to learn from explicit information about risky choices in a gambling task. More specifically, Rogers et al. [31] demonstrated that patients with orbitofrontal cortex (OFC) damage were impaired when making risk-taking choices. Functional neuroimaging studies on healthy adults have reported activation related to risk-taking decision making in the OFC [14,20], the inferior prefrontal cortex (PFC) [26,27], the ventrolateral and ventromedial frontal cortices [8,9], the insula [6], and the parietal regions [27].

Efficient and effective regulation of impulsiveness [23] is an essential prerequisite for advantageous risk-taking decision making. Previous studies have consistently reported significant activation in the lateral PFC and the ACC when participants were exercising inhibitory control [16,17]. The lateral PFC and ACC regions work collaboratively to regulate impulsiveness and to ensure the smooth operation of the risk-taking decision-making process.

This fMRI study examined the neural activities associated with risk taking. The sample consisted of people who were categorized as having High or Low levels of impulsiveness according to their scores on the Barratt Impulsiveness Scale (BIS; 24). Participants' risk-taking behaviors in the two groups were matched according to their performance on the Risky-Gains task (27, with permission) so that differences in neural activations could be explained by the different neurocognitive processes associated with risk taking rather than their behavioral differences [19]. The Risky-Gains task was used to examine the neural activities associated with making a risk-taking decision and receiving the feedback as the consequence of that decision (see Fig. 1). The task requires the participant to acquire as many points as possible by choosing between safe (20 points)

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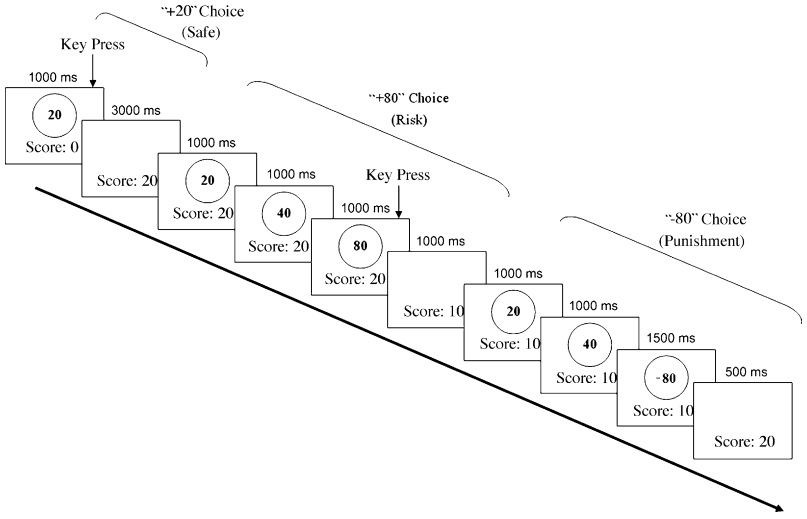

Fig. 1. Schematic representation of the experimental paradigm – the Risky-Gains task.

and risky (40, 80 points) options. In each trial, point options (20, 40, 80) are presented in a fixed sequential order. The participant claims the points by pressing a button when the points appear. The participants always get +20 points because it is "safe" but the other points can be a reward (+40/+80) or punished (−40/−80) options. Immediate feedback is given to the participant. An event-related design was used and each participant completed 96 random trials inside a MRI scanner. Each trial lasted 3.5 s, irrespective of the participant's response.

We performed contrasts comparing "risky versus safe responses" (risk taking), and "punished versus safe responses" (punishment). Specifically, the risk taking contrast could reflect brain activities associated with those cognitive processes underlying the selection between risky and safe options. The punishment contrast reveals brain activities associated with the reaction towards being punished versus rewarded. We performed region of interest (ROI) analyses in the bilateral insula, the OFC, and the parietal regions in order to assess their involvement in the risk-taking decision-making process [27]. The same analyses were performed in the ACC and lateral PFC because these regions are involved in the regulation of impulsiveness [16]. Since the participants differed in their level of impulsiveness but were matched in terms of their risk-taking behaviors, we hypothesized that different patterns of neural activation would be observed in the ACC-lateral PFC regions, but not in the brain regions subserving risk-taking decision making (i.e. the insula–OFC–parietal regions).

Eighteen healthy volunteers (8 females and 10 males), recruited from the community, participated in this study. All the participants were strongly right-handed [37]. They had no previous history

Table 2
ROI analysis of the high versus low impulsivity contrast in the risk versus safe and punish versus safe contrasts

level of activation of the posterior parietal region could alternatively suggest that those in the high impulsiveness group need to recruit additional neural resources from the parietal regions for regulation of impulsive outputs [16].

The comparable neural activations in the lateral PFC–ACC regions between the high and low impulsiveness groups were unexpected. This observation is quite different from the data obtained from clinical populations [16] using various experimental paradigms [4,28,29]. Given the multi-component nature of the construct of inhibition [24,25], it is possible that the variance captured by the BIS are different from that reflected by the PFC–ACC activations. On the other hand, the nonsignificant group differences in the lateral PFC–ACC activations may be due to the fact that our participants were healthy individuals who showed only a very narrow range of variation in their level of impulsiveness. This together with the small sample sizes are limitations that restricted the statistical power of our observations. More participants with a broader range of impulsiveness should be recruited in future studies to increase the between-group variance and to confirm our current findings.

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