Separate neural systems for evaluating risks and reward in decision making

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Introduction. Our choices have different degrees of risk. Risk can be expressed as the probability of winning; the scale of wins vs. losses; or a function of both such as the expected utility. We used a novel gambling task to study the different dimensions of risk – probability vs. outcome – and the distinct roles of orbitofrontal cortex (OFC), anterior cingulate cortex (ACC) and ventral striatum (VS) in mediating risky decision making.

Methods. The task balances different risk choices, matching approximately the net gain for high and low risk choices. Trials had 3 phases (Fig. 1) (i) a cue with the cumulative winnings and the stake for the current trial (ii) choice of seven cards in two groups with associated rewards (iii) an outcome phase. From a fair deck, subjects chose which set of cards had the 'ace of hearts'. The group with fewer cards has a higher risk and higher reward. A wrong choice loses the stake, the right choice wins the reward (paid as Danish kroner at the end of the study: 1 kr ~15 US cents). There is a net gain for all subjects over the experiment. 30 subjects underwent fMRI at 3T and SPM5 was used to model (1) choice phase, parametrically modulated by risk level (1/7, 2/7…6/7) (2) outcome phase, parametrically modulated for won trials according to the winnings-value and for lost trials by the value of missed winnings.

Results. Behaviour: choices were balanced across risk levels. This probably reflects the matching of net gain for high and low risk trials. fMRI: the proportionate risk level correlated with enhanced activity in the rostral VS, dorsal-ACC, insula and OFC (red, Fig. 2). In "win" trials, the magnitude of winnings correlated with outcome related activity in caudal ventral striatum and subgenual-ACC (green). In the context of losing a trial, we found no significant correlations between outcome related regional activation and the magnitude of the missed winnings.

Conclusions. Ventral striatum and anterior cingulate cortex are sensitive to the proportionate risk associated with choices. However, separate regions of both VS and ACC are sensitive to the magnitude of reward following a successful choice, independent of risk. These neuroanatomical functional differences may be influenced by individual differences in personality, psychiatric illness or addiction.

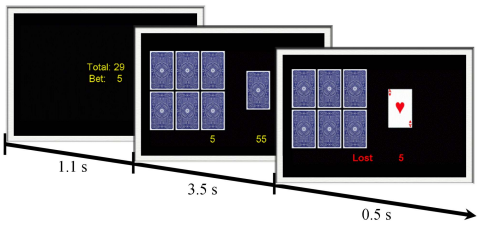

Fig. 1. A trial with three separate phases: Informative, choice and outcome phase

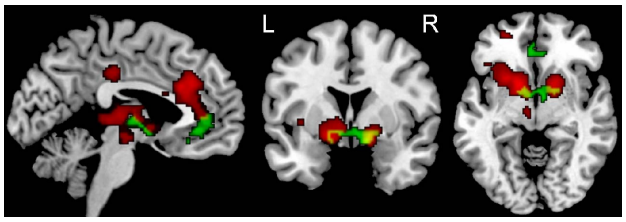

Fig. 2. Statistical map showing correlations for assumed risk (red) and relief (green) (Illustrated at voxelwise threshold p<0.0003 uncorrected: OFC, ACC and VS activations at p<0.05 within regions of interest)