Reward uncertainty and decision uncertainty independently modulate activity in brain systems for decision making

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Studies of decision making often focus on decision making under uncertainty: that is, when information about the probabilities of different outcomes is limited. Models of decision making under uncertainty posit a dorsal prefrontal-parietal system, with dorsolateral prefrontal cortex (dlPFC) supporting decision-related processes, and posterior parietal cortex supporting the evaluation of the expected outcome of decision options. However, some decisions are made under uncertainty but under risk: that is, when the probability of different reward outcomes is known. The processing of the reward consequences of actions has been linked to ventromedial prefrontal cortex (vmPFC), while the selection and control of risky behaviors has been linked to insular cortex.

We used fMRI to investigate the brain systems that support decision making in the presence and absence of uncertainty and risk. On each trial, subjects viewed a simple stimulus, executed a response, and received reward feedback. Some of the stimuli were associated with predetermined decisions and/or reward probabilities, while others were not. Subjects were trained on all stimulus-response contingencies before entering the scanner, and behavioral performance was near ceiling.

We hypothesized that, as shown in previous studies, there would be significant decision-phase activity in dlPFC and related brain regions. Likewise, we hypothesized that there would be significant reward-phase activity in vmPFC and related brain regions. Of key interest were the effects of reward information upon decision-related activity. The hypothesis that fMRI-related risk information guides decision-making activity in vmPFC would increase for risky trials. Furthermore, if the insular cortex supports the control of risky behavior, not only should its activity increase in unexpected absences of reward, but it should be sustained until the subsequent trial.

Behavioral Methods:
- Subjects: 12 young adults, (18 – 29y)
- Subjects averaged >96% correct on the task (only 2% below 96%), all showed minimal head motion.
- Experimental Task:
  - Subjects viewed a single shape that was predictive of a subsequent response, then made a left or right button press to a response cue (T), and then saw a feedback stimulus that indicated the delivery (S) or absence (N) of a monetary reward. (See DESIGN)
  - Four of the five shapes always mapped to a particular response, the correct response to the fifth was randomized.
  - Each shape mapped to a fixed probability of reward given a correct response: 100%, 75%, or 50%.
- Stimulus Timing:
  - Context stimulus: 250ms
  - Context Response interval: 3000ms
  - Response_FEEDBACK interval: 2000-8000ms
- Trial-trial interval: 2000-8000ms.

FMRI Methods:
- Data acquired using fMRI at 4T:
  - BOLD contrast T² weighted with spiral-out pulse sequence (TR, 1500ms; TE, 35ms; flip angle, 90°)
  - Voxel size: 3.75*3.75*3.8mm
  - 34 axial slices parallel to AC-PC line
- Image Preprocessing:
  - Motion correction, slice timing correction.
  - Normalization, and spatial smoothing (SPM 99).

FMRI Analyses:
- Average epochs were created timedlocked to the onset of the decision and reward stimuli.
- Decision Phase: Epochs were correlated with reference waveform and compared across subjects using a random effects analysis (p < 0.0001).
- Reward Phase: The difference between rewarded and unrewarded trials (75% condition) was compared using a t-test across all subjects (p < 0.001).

INTRODUCTION
- Under conditions of decision certainty, significant activity was found in a prefrontal-parietal decision system, as well as in visual and motor regions.

METHODS

1. Reward uncertainty (risk) can be evoked in the absence of decision uncertainty.
2. A double dissociation exists between dlPFC & vmPFC; the former supports decision-related processes, the latter reward-related processes.

CONCLUSIONS

1. Reward uncertainty (risk) can be evoked in the absence of decision uncertainty.
2. A double dissociation exists between dlPFC & vmPFC; the former supports decision-related processes, the latter reward-related processes.

3. Reward-related activity in the vmPFC depends on the perceived reward uncertainty.
4. The insula supports the control of behavior following reward feedback.
5. Reward uncertainty influences activity within decision-making regions.