Supplementary Figure 1

Behavioral performance in the strategy and option decision tasks conducted with two choices for both tasks.

The tasks were similar to those used in the fMRI experiments, except that 1) the number of choices was two for both strategy and option decision tasks; 2) the choices were shown together with the board position from the beginning; 3) the subjects could press a button even during the presentation of board position; and 4) the time up occurred 4 s after the termination of the board position. Eight experienced amateur players (27–55 y/o, amateur 3–4 dan) participated in these psychological experiments. The subjects were instructed to make a response as soon as they reached a high self-confidence (~80%) on their choices. During debriefing, one subject reported that he made his responses towards the end of each trial after carefully confirming his choices. Another subject reported that he largely gave up evaluating the two choices in the option decision task and selected one just by gut feeling. We removed these two subjects from the analyses. (a) Response times in the strategy and option decision tasks. A circle represents a subject. The response time in the strategy decision task (on average 4.0 s) was significantly shorter than that in the option decision task (on average 4.4 s) \( (P = 0.0098, \text{two-tailed paired } t \text{ test; Cohen’s } d = 3.2) \). (b) The percentages of correct responses in the strategy and option decision tasks. The response accuracy in the strategy decision task (on average 68%) was significantly higher than that in the option decision task (on average 48%) \( (P = 0.00054 \text{ by two-tailed paired } t \text{ test; Cohen’s } d = 5.9) \). These psychological results demonstrate that making a strategy selection was faster than making an option selection and that the subjects made fairly good strategy decisions without knowing the best options of next move (close to the chance level, 50%).
Supplementary Figure 2

Strategy values as independent variables of the logistic regression of subjects’ selections.

(a) Coefficients for values of the n-th best moves (n = 1–10) in the two-dimensional model when each pair of attack and defense values of the same rank alone was entered into the model. Coefficients for attack (a1) and defense (a2) are shown in the upper and lower halves, respectively. The ordinate of the lower half is inverted. (b) Coefficients for mean values of the best n moves (n = 1–10) in two-dimensional model when each pair of mean values was entered into the model. (c) The Akaike’s information criterion (AIC = −2logL + K, where logL is maximum log-likelihood function for the estimated model, and K is the number of parameters) for mean values of the best n moves. Mean values of the best three moves gave the best fitting (the minimum AIC). (d) The Akaike’s information criterion shows that the 2-dimensional model was better than the 1-dimensional model (P = 0.000081). The Bayesian information criterion (BIC = −2logL + K × logN, where N is the number of observation) also showed that that the 2-dimensional model was better than the 1-dimensional model: the BIC for the fitting by the two-dimensional model was 2.40 less than that for the fitting by the one-dimensional model (P = 0.0080). Mean values of the best three moves were used in these comparisons. Error bars indicate S.E.M. across subjects.
Response time was longer when differences between subjective values of chosen and unchosen strategies were smaller \((r = 0.41, P = 0.039, z\ test)\). This suggests that the task was more difficult when difference between subjective values of alternative strategies was small. Error bars indicate S.E.M. across subjects.
Supplementary Figure 4

Response bias was not associated with response times.

(a) Response times were not different between attack and defense selections ($P = 0.37$, two-tailed paired $t$ test). (b) The difference between mean response times for attack and defense selections in each subject was uncorrelated with his response bias ($r = -0.076$, $P = 0.39$, $Z$-test). Each data point indicates a subject.
Supplementary Figure 5

Mean activities in rACC and PCC during defense and attack strategy selections in the three subjects who had response bias toward defense.

The data of the three subjects were pooled using a fixed-effect analysis. rACC activities were higher during defense selection than during attack selection ($P = 0.032$, two-tailed unpaired $t$ test) and PCC activities were higher during attack selection than during defense selection ($P = 0.0017$). Error bars indicate S.E.M. across trials. *, $P < 0.05$; **, $P < 0.01$. 
Supplementary Figure 6

The diagram of functional interaction among rACC, PCC and DLPFC during strategy decision.
Supplementary Figure 7

Activities in the ventral PCC (vPCC).

(a) Activations determined by the contrast of decision-making period versus "Gold"-piece detection period in all task trials (yellow). The cyan circle circumscribes vPCC. The dorsal activation was located in the precuneus. (b) vPCC was comparably activated in all trial types ($F_{[1,102]} = 2.1, P = 0.15$, one-way ANOVA). Error bars indicate S.E.M. across subjects.
Supplementary Figure 8

The strategy decision was not associated with affective responses.

(a) The heart rates in attack and defense selections in the strategy selection task were not different from each other ($P = 0.26$, two-tailed paired $t$ test). The heart rate was normalized by the values during the inter-trial intervals of all trials in each subject. (b) The regions (ventral striatum and amygdala) thought to be associated with affective responses were not activated during the strategy task ($P = 0.32$ in ventral striatum and $P = 0.24$ in amygdala, two-tailed paired $t$ test, the minimum $P$ value among the six conditions). Error bars indicate S.E.M. across subjects.
Supplementary Figure 9

The dorsal ACC (dACC) was not activated during decision-making in either the strategy decision task or the option decision task.

The ROI for the analyses here was defined by the peak coordinate for encoding of search value (peak Tal: [–4, 32, 17], radius: 10 voxels) in Kolling et al. (2012). (a) dACC was neither activated during strategy decision nor during option decision ($P = 0.35$, two-tailed paired $t$ test, the minimum $P$ value among the six conditions). (b) fMRI activity time courses in dACC during trials of the strategy and option tasks. There was a significant activation in trials of the option task, but it occurred after the selection was completed. The grey bar indicates the problem presentation time.
Supplementary Figure 10

The ventromedial PFC (VMPFC) was neither correlated with subjective strategy values in the strategy decision task, nor with the chosen value in the option decision task.

The regressor encoding the value of chosen option during the option decision task was analyzed only in the trials where the subjects chose one of the three concrete options other than “the other options” (about 60% trials). The VMPFC ROI (blue) for the analyses here was defined by the peak coordinates for encoding of subjective values (peak Tal: right, [3, 32, –3]; left, [–8, 35, –2], radius: 10 voxels) in Levy & Glimcher (2012). (a) The location of VMPFC ROI, which is ventral to the rACC region (red). (b) The estimated parameters of fMRI signals in VMPFC associated with $S_{ASV}$, $S_{DSV}$ and $S_{chosen} - S_{unchosen}$ in the strategy decision task, and associated with the chosen values in the option decision task. None of them were significantly different from zero ($P = 0.21$, two-tailed paired $t$ test, the minimum $P$ value among the four conditions). Error bars indicate S.E.M. across subjects.