Primary motor cortex encodes relative action value signals that integrate stimulus value and effort cost at the time of choice

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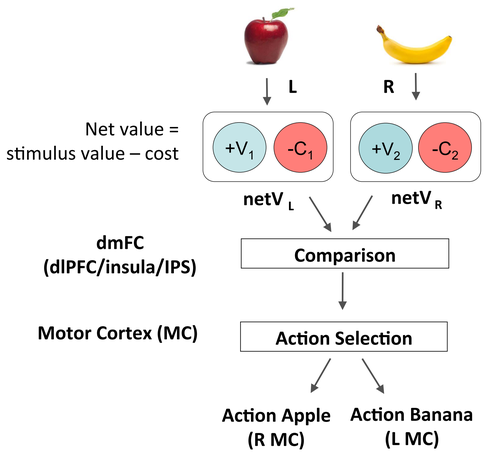
Introduction

- Decision depends on both stimulus value and effort cost. (e.g., vending machine vs. 1 mile walk to a cafe).
- To make a choice involves effort costs, the brain needs to assign value and cost estimates, integrates them into a single net value for each option, and then compare the net values to choose the best action.
- Little is known how the computations of these variables are implemented in the brain, particularly in the motor cortex.

Hypothesis

- We hypothesized that

1. The neutral comparator regions that includes dorsomedial frontal cortex (dmFC) would integrate stimulus value and effort cost into the overall net values, and then compare them.
2. motor cortex would encode relative action values in a form of "contralateral – ipsilateral net values."



- Neural Comparator signals (unchosen – chosen)

$$\text{Net Value}_{unchosen} - \text{Net Value}_{chosen}$$
$$(\text{Stim V}_{unchosen} - \text{Effort C}_{unchosen}) - (\text{Stim V}_{chosen} - \text{Effort C}_{chosen})$$
$$(\text{Stim V}_{unchosen} - \text{Stim V}_{chosen}) - (\text{Effort C}_{unchosen} - \text{Effort C}_{chosen})$$

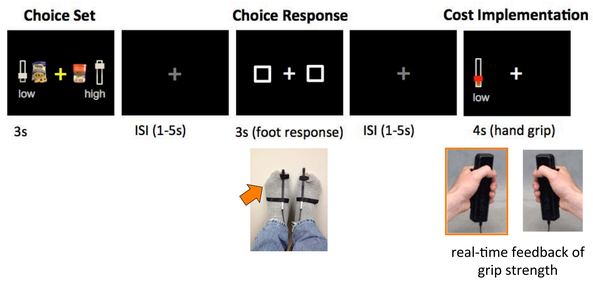
Methods

PARTICIPANTS: 27 right-handed subjects
STIMULI: 45 appetitive food items (e.g., chocolate, potato chips)
PHYSICAL EFFORT: 3 levels from subject's maximum grip strength (Low 25%, Medium 50%, Hi 75%)

IMAGING: 3T, TR 2.78 sec, 3mm isotropic voxel, oblique (30°)

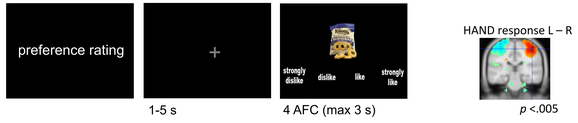
Task

Two-item choice task: 3 runs (135 choices)



- Each food item was randomly paired with one of 3 levels of effort cost (low, medium, high).
- Subjects exerted chosen effort level for > 2 sec on each trials.

Localizer 1. Liking-rating task (hand button response)



- These ratings were used as subjective stimulus value measures of foods
- This task also used as a functional localizer of vmPFC and HAND motor cortex.

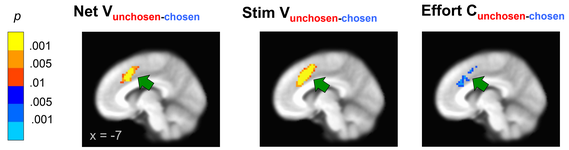
Localizer 2. Binary choice task (foot response)

- This task was used as a functional localizer of neural comparator regions and FOOT motor cortex.

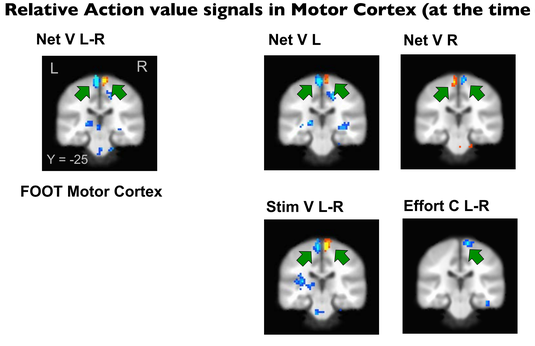
Results

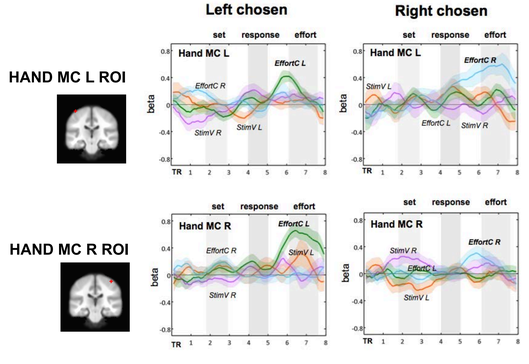
fMRI

1. Neural comparator signals (Unchosen netV– chosen netV)

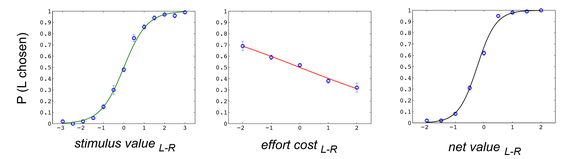


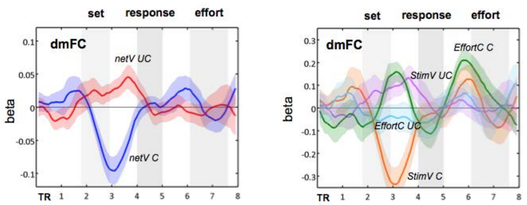
2. Relative Action value signals in Motor Cortex (at the time of choice)

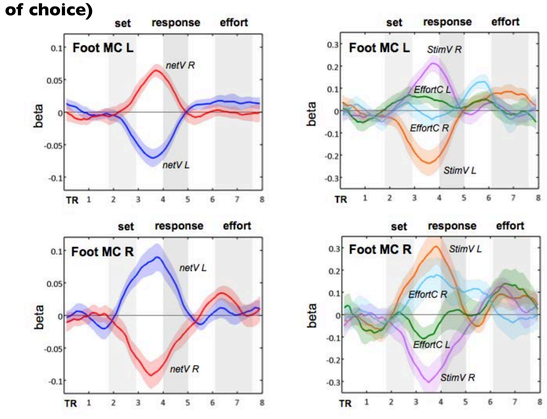




Behavior : Logistic psychometric choice curves







Conclusions

1.The dorsomedial frontal cortex (dmFC) encodes relative net comparator value signals (net value: unchosen - chosen) that integrate stimulus value and effort cost.

2. The foot areas in primary motor cortex encode relative net action value signals (net value: contralateral – ipsilateral).

3. To the contrary, both left and right hand areas in the primary motor cortex reflected anticipatory activities for the effort cost of the chosen option.

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