Project Proposal:
Value signals in the orbitofrontal cortex incorporate reference-dependent surprise utility

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Introduction

Everyday we are faced with choices that yield hedonic responses. These responses are encoded in the brain as experienced utility signals, which can be found in the orbitofrontal cortex (OFC) [1–9]. These signals are used to learn the value of actions and stimuli, and affect memory encoding and retrieval [10, 11]. A key question in neuroeconomics and behavioral economics is what affects experienced utility. For example, is it influenced only by outcomes, or also by beliefs?

Behavioral economists have proposed expectations-based models of reference dependence [12–14] that incorporate deviations from expectations ("surprise") into experienced utility. Under these models, experienced utility can be represented as:

$$U(x|p) = (1-a) * u(x) + a * (u(x) - E[u(x)|p]) \tag{1}$$

where a is a weight that captures the degree with which surprise modulates experienced utility, $u(x)$ is a utility function that captures the utility derived from consuming x, p is the probability over potential values of x, and E is an expectations operator. The first term represents the proportion of experienced utility that is the direct pleasure derived from consuming x (i.e. the "consumption" component). The second term represents the proportion of experienced utility that is derived from the deviation of experienced pleasure from ex ante expectations (i.e. the "surprise" component).

Although this class of models have become quite influential in behavioral economics, and are capable of explaining some puzzling phenomena, the fundamental assumption that experienced utility depends on both consumption and surprise has not been tested. Here, I propose to combine fMRI with a carefully designed task to test this approach.

Task

To understand if neural signals of experienced utility incorporate the surprise component of utility, I propose a human fMRI study where subjects are first shown the probabilities

of receiving an appetitive or neutral liquid (e.g. juice vs. neutral) in the form of a pie chart (see Figure 1). After subjects are exposed to the probabilities, either an appetitive or neutral liquid will be inserted into their mouth. They will hold the liquid in their mouth for 6 seconds before being cued to swallow in order to generate a hedonic response. During this 6 second window, we will capture BOLD activity in the OFC, the region previously found to encode appetitive and aversive goal values [1–9].

Depending on the probability of receiving the appetitive liquid (which generates expectations), the subject may be more or less surprised by the outcome. The probability of the appetitive liquid is $p \in \{0, 1/3, 2/3, 1\}$. $1/6^{\text{th}}$ of all trials will be certainly neutral ($p = 0$), $1/6^{\text{th}}$ of all trials will be certainly appetitive ($p = 1$), $1/3^{\text{rd}}$ will be unlikely appetitive ($p = 1/3$), and $1/3^{\text{rd}}$ will be likely appetitive ($p = 2/3$). I will run 3 blocks of 40 trials each, with each block lasting around 13 minutes. To limit satiety, subjects may consume a maximum of 60 ml of juice throughout the course of the experiment.

I will ask subjects to refrain from drinking any liquids for 4 hours prior to the experiment. When they arrive at the experiment, they will taste a small quantity of 14 different liquids and rate the pleasantness of each on a scale from -5 to 5. The highest rated juice will serve as the appetitive outcome, and a solution made up of water and the ionic components of saliva will serve as the neutral outcome.

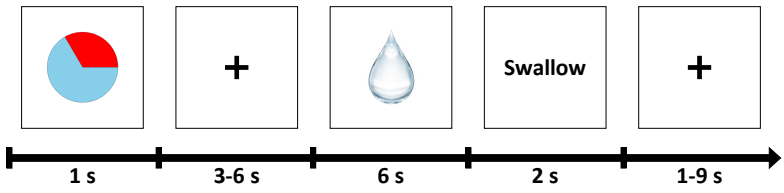

Figure 1: **Trial timeline.**

Hypotheses

If experienced utility signals in the OFC are independent of the surprise component of reference-dependent utility, then we expect neural signals of value to be at baseline when the neutral liquid is rewarded and to be high when the appetitive liquid is rewarded, regardless of the initial probability of appetitive liquid that was presented at the beginning of the trial. See Figure 2A for predictions of experienced utility signals independent of surprise.

In contrast, if experienced utility signals are dependent on the surprise component of reference-dependent utility, then we expect neural signals of value to scale with the amount of surprise that the outcome induces. For instance, if the appetitive reward is likely ($p = 2/3$) but the outcome is the neutral solution, we expect a lower signal than if the appetitive reward is unlikely ($p = 1/3$) and the outcome is the neutral solution. Similarly, we expect neural signal to be monotone decreasing in the probability of appetitive reward. See Figure 2B for predictions of experienced utility signals modulated by surprise. A comparison of the BOLD responses in the OFC during the degustation period will provide the key test of the hypotheses.

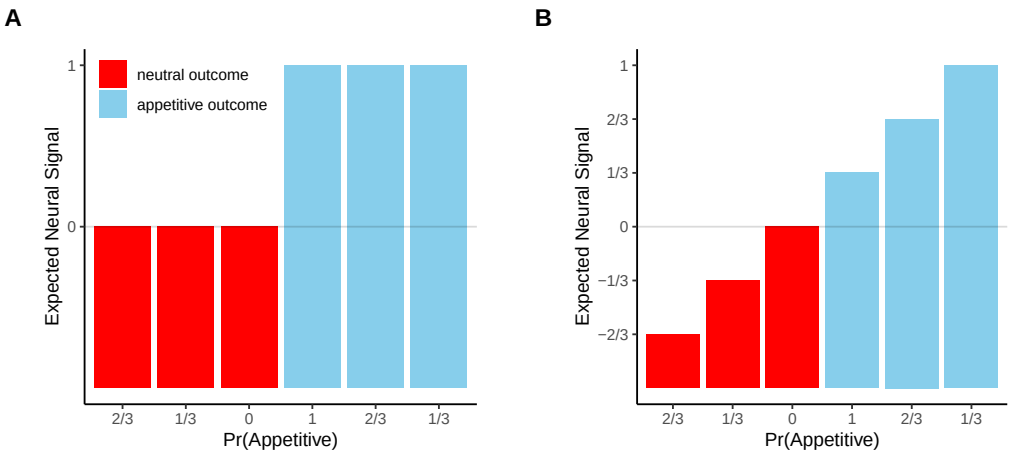

Figure 2: **Predictions of BOLD activity in OFC.**

How does this experiment differ from ongoing research in my lab?

A former PhD student played with a related experiment about 10 years ago, but couldn't get it to work. Nobody else in the lab has worked on this topic for over a decade. I'm eager to work in this area because using neuroeconomic tools to test basic models in behavioral economics is my main area of interest.

Budget Justification

The funds from this grant will be used to run a pilot study. Should there be promising results, Professor Rangel has agreed to fund future data collection for a full project.

Budget Proposal

I aim to collect data from 18 subjects. Each subject will be paid a $35 show-up fee. Renting the fMRI scanner will cost $490 per hour, and we expect each session to run for 1 hour. I will purchase 14 different juices for every 3 subjects at roughly $5 per juice container. **In total, the experiment will cost $9,870.**

References

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