Comment on "The Involvement of the Orbitofrontal Cortex in the Experience of Regret"

Regret is an emotion that accompanies negative outcomes to decisions for which we have been responsible (*1*). Given a choice between two gambles, subjects will experience regret if the unchosen gamble yields a higher reward than the chosen gamble (*2*). Camille *et al*. (*3*) hypothesized that the anticipation of regret is useful for steering decision-making and, to this end, tried to show that normal controls perform better on a gambling task than patients with lesions of the orbitofrontal cortex (OFC), who do not appear to experience regret. However, the parameters of their gambling task raise the possibility of alternative explanations.

Camille *et al*. set out to "test the prediction that advantageous choice behavior depends on the ability to anticipate and hence minimize regret" (*3*). Yet it is not generally true of gambling tasks that anticipated regret is helpful, and it is especially not true in the task they describe. As will be made clear below, it is only because of the design of their task that they obtained the apparent result that normal controls (who experience regret) outperformed the OFC patients (who do not experience regret).

Specifically, the authors present subjects with two gambles; the subject picks the one she wants to play, and in the "complete feedback" condition she sees both its outcome and the outcome of the unchosen gamble. Camille *et al*. suggest that OFC patients make their choice largely based on the expected value (EV) of the two gambles, whereas normal controls also take into account a measure of anticipated regret, which encodes the difference between what they might get and what they might have gotten. In their notation, when presented with two gambles, the anticipated regret from choosing gamble 1 is $r = |y_2 - x_1| - |y_1 - x_2|$, where x_1 and y_1 are the possible outcomes of gamble 1 and x_2 and y_2 are the possible outcomes of gamble 2 (x_1 and x_2 are always higher than y_1 and y_2). Minimizing anticipated regret means avoiding the possibility of a big negative value when, in the future, you compare what you got to what you could have had.

To understand the role of anticipated regret in decision-making, we simulated the game with the exact parameters prescribed by Camille *et al*. Possible outcomes consist of any pair of the values +50, –50, +200, and –200 associated with different outcome probabilities (0.8, 0.2, or 0.5). Because of the structure of this task, a gambler who makes decisions based only on the highest EV will outperform one who makes decisions based on anticipated regret; they will earn averages of 1930 and 1447, respectively ($P < 4 \times 10^{-6}$; t = 4.7; weighted combinations of EV and anticipated regret will show intermediate performance) (Fig. 1A). In other words, as every economist knows, in this task one should make decisions based on expected value: Adding regret into the mix will reduce the total winnings. Examining the gambling outcomes of Camille *et al*. (Fig. 1B) therefore raises two questions: (i) why did Camille *et al*. find superior performance when regret was involved (normal controls), and (ii) why do the total winnings from 30 trials come out in the thousands (Fig. 1A), when the subjects in Camille *et al*. only earned in the hundreds (Fig. 1B)?

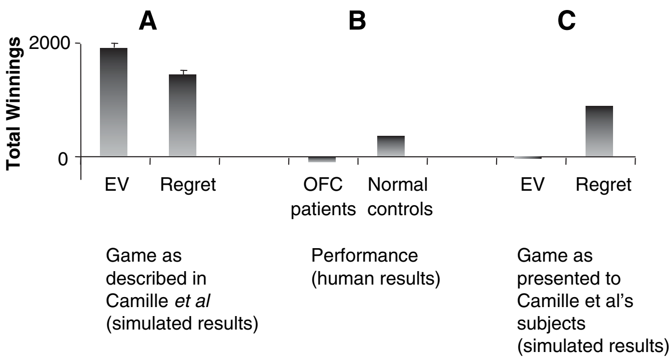

Fig. 1. To examine the structure of these tasks, a simulation was programmed in which 100 subjects played 30 trials each. (**A**) Game parameters were generated randomly for each subject, following exactly the set of rules described in (*3*). Total winnings result from decision-making based on expected value (EV) of the gambles or based on anticipated regret. Error bars = SEM (**B**) Gambling outcomes for OFC patients (–110) and controls (+366) as reported in (*3*). Error bars not reported. (**C**) Outcomes from playing task parameters used in (*3*) [see table S2 in (*4*) for parameters]. MATLAB code available at http://nba.uth.tmc.edu/homepage/eagleman/regretcode.m.

This discrepancy is entirely based on the way the game was structured when Camille *et al*. actually presented it to subjects, which requires examining the fine print. We must draw a distinction between the two-gamble task described in (*3*) and the task as it was actually presented to the participants in the study. When it comes to what was actually presented, the authors only note that "the gamble with the highest expected value won less often on average than the one with the lowest expected value" (*3*). In other words, if $EV(g_1) > EV(g_2)$, the depicted probability of winning x_1 (either 0.2, 0.5, or 0.8) was not the actual probability of winning. Instead, the real probability of obtaining the high reward (x_1) was lower and the probability of obtaining the low reward (y_1) was higher. Although this manipulation was reportedly implemented to yield more trials with negative emotions, it introduces troubling confounds.

To understand the difference in the described and presented task, we obtained from the authors the actual parameters presented to subjects [table S2 in (*4*)]. Note that with these parameters, the actual probabilities of winning the higher rewards (x_1 or x_2) are engineered to be less than the depicted probabilities (p and q). When simulated subjects are run with those parameters, an inversion happens: Here, incorporating anticipated regret yields a higher return. That is, a gambler minimizing anticipated regret earns 900, whereas one following EVs earns 0 (Fig. 1C). (Again, any weighted combination earns an intermediate return.) In this presented task, the inclusion of anticipated regret improves performance.

The problem is that designing the game this way raises the possibility that the OFC patients were simply less adept than normal controls at picking up the fact that the real probabilities of winning the high reward were chronically smaller than the depicted probabilities. If true, this might mean the signal influencing the behavior of normal controls does not represent avoidance of regret but, instead, suspicion or frustration. Measures of emotional reactivity (such as skin conductance response) would be unlikely to distinguish these possibilities.

A more straightforward and convincing way to determine whether anticipated regret is driving behavior (as opposed to suspicion, frustration, and the like) would be to determine whether OFC patients perform better than normal controls in a more appropriately designed version of the task (Fig. 1A). A superior performance would provide counterintuitive and sound evidence that they are not using anticipation of regret to steer (and diminish) their performance. Indeed, new evidence shows that emotion can play a disruptive role in gambling tasks and that lesion patients defective in emotional processing can make more rational decisions than normal controls (*5*).

There seems little doubt that brains simulate and evaluate possible futures (*6–9*); these simulations include questions such as, "How bad will I feel if I lose this gamble?" What remains to be clarified is when and how these evaluative signals are involved in decision-making (*10*) and when they are advantageous. Many investigators suspect that regret signals will likely be important to decision making; however, the design of the Camille *et al*. study may render it unable to address this point.

David M. Eagleman
Department of Neurobiology and Anatomy
University of Texas, Houston, Medical School
and
Department of Psychology
Rice University
Houston, Texas
and
Institute for Neuroscience
University of Texas, Austin
E-mail: deagleman@uth.tmc.edu

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