Response to Comment on "The Involvement of the Orbitofrontal Cortex in the Experience of Regret"
Giorgio Coricelli, et al.
Science 308, 1260c (2005);
DOI: 10.1126/science.1108099

The following resources related to this article are available online at www.sciencemag.org (this information is current as of December 8, 2009):

Updated information and services, including high-resolution figures, can be found in the online version of this article at:
http://www.sciencemag.org/cgi/content/full/308/5726/1260c

Supporting Online Material can be found at:
http://www.sciencemag.org/cgi/content/full/308/5726/1260c/DC1

A list of selected additional articles on the Science Web sites related to this article can be found at:
http://www.sciencemag.org/cgi/content/full/308/5726/1260c#related-content

This article cites 4 articles, 1 of which can be accessed for free:
http://www.sciencemag.org/cgi/content/full/308/5726/1260c#otherarticles

This article appears in the following subject collections:
Neuroscience
http://www.sciencemag.org/cgi/collection/neuroscience
Technical Comments
http://www.sciencemag.org/cgi/collection/tech_comment

Information about obtaining reprints of this article or about obtaining permission to reproduce this article in whole or in part can be found at:
http://www.sciencemag.org/about/permissions.dtl
Response to Comment on "The Involvement of the Orbitofrontal Cortex in the Experience of Regret"

Standard economic theory can account for human choices in a variety of situations. It predicts that rational decision-makers will base their choice on the probability that a particular outcome will be favorable (i.e., its expected utility). However, many deviations from this prediction are observed, because humans are often anything but rational. For example, people often prefer getting $450 with 100% certainty than $1000 with 50% probability, even though the expected value of the second option ($500) is higher than the first one ($1). In the Netherlands, the "postal code" lottery is immensely popular even though playing the game is quite irrational (2). Its success has been explained by the possibility that people figure how bad they would feel if, not having bought a ticket, their postal code is drawn and their next-door neighbor wins the lottery. Such counterfactual reasoning is what allows us to anticipate future regret. Whether this is ultimately useful probably depends on what is at stake, for example, money, reputation, or the well-being of loved ones. When gambling, a purely rational mind fast at computing the expected value of the different options is most certainly one's best asset. However, human beings do not necessarily operate in a purely rational fashion.

Patients with orbitofrontal cortex lesions (OFC) can elaborate plans and options and even recognize the incongruence between how they should behave and how they actually behave (3), yet in real life their choices are inadequate in a manner suggesting a missing sense of responsibility for the consequences of their own decisions. This common clinical observation predicts that such patients should not feel regret and that their choices should not be weighted by possible future regrets. Camille et al. (4) explicitly tested this prediction. The comment by Eagleman (5) challenges two aspects of our study and argues that way, whereas OFC patients might have been insensitive to this mismatch and performed the task solely according to expected values. Unfortunately, Eagleman's argument fails to account for several findings.

Eagleman neglected one key aspect of the experiment: the comparison between partial and complete feedback. The mismatch between the expected and actual outcomes was present in both conditions because they were made from the same gamble pairs. If patients were insensitive to this mismatch, and experienced no frustration, why were their choices not significantly different from those of normal subjects in the partial feedback condition? A model that would factor in frustration should account for choice behavior whether or not feedback on the outcome of the rejected gamble is provided.

This logic also applies to emotional ratings, a dependent variable that should be particularly sensitive to feelings of frustration. Normal subjects and OFC patients exhibited similar, graded emotional responses in the partial feedback (see figure 2, A and B, in Table 1. Model of choice applied in a replication of the task used in (4), with actual outcomes matching depicted probabilities. Dependents variable is "choice." With $d$ = anticipated (minimization) disappointment, $r$ = anticipated (minimization) regret, and $e$ = maximization of expected value [data from (6)]. Results show that normal subjects chose maximizing expected values and minimizing regret, whereas OFC patients did not anticipate regret. Therefore, we found the same pattern of choice behavior observed in (4).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>.2251687</td>
<td>.1541618</td>
<td>1.46</td>
<td>0.144</td>
</tr>
<tr>
<td>$d$</td>
<td>-.0015986</td>
<td>.0018395</td>
<td>-0.87</td>
<td>0.385</td>
</tr>
<tr>
<td>$r$</td>
<td>.0068114</td>
<td>.00173719</td>
<td>4.97</td>
<td>0.000</td>
</tr>
<tr>
<td>$e$</td>
<td>.0304755</td>
<td>.0038502</td>
<td>7.92</td>
<td>0.000</td>
</tr>
<tr>
<td>OFC patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-.3838773</td>
<td>.5012885</td>
<td>-0.77</td>
<td>0.444</td>
</tr>
<tr>
<td>$d$</td>
<td>-.023136</td>
<td>.0100615</td>
<td>-2.3</td>
<td>0.021</td>
</tr>
<tr>
<td>$r$</td>
<td>.0047578</td>
<td>.0043964</td>
<td>1.08</td>
<td>0.279</td>
</tr>
<tr>
<td>$e$</td>
<td>.0669018</td>
<td>.0223844</td>
<td>2.99</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Fig. 1. Emotional ratings in a replication of the task used in (4), with actual outcomes matching depicted probabilities. Ratings were made by 17 normal control subjects (A) and 2 orbitofrontal patients (B) for two obtained outcomes (-50 or 50) as a function of the outcome (blue line and symbols, -200; red line and symbols, 200) of the unchosen gamble in the complete feedback condition [data from (6)]. The outcome of the alternative gamble strongly modulates the emotional rating (regret effect) of normal subjects but not that of OFC patients.
and to the contrast between what they hoped to obtain and what they actually obtained [figure S2 in (4)]. If only normal subjects, but not patients, reacted with frustration to the mismatch between expected and actual outcomes, differences in subjective emotional ratings between the two groups should have been observed in both conditions. Also, normal subjects did not generally react more negatively than patients to losing, as a frustration hypothesis might predict.

Our core argument is that knowing the result of the alternative gamble, as compared with knowing only the result of the chosen gamble, generates a specific emotion that we called regret. Following our hypothesis, regret biased subjects’ choice throughout the experiment. The effect of anticipated regret was confirmed by our model of choice (4), where we found an interaction between maximization of expected value (\( e \)) and minimization of future regret (\( r \)). Is this result confounded by the possibility that the parameters we used created frustration rather than regret? As part of another recent study (6), we had 17 normal subjects and 2 OFC patients perform exactly the same task, but this time using outcomes that matched the depicted probabilities. The results on emotional rating (Fig. 1 and fig. S2) confirm our original findings. The same model also showed that anticipated regret significantly contributes to the gambling choices of normal subjects’ but not those of OFC patients (Table 1). Patients performed in a manner consistent with rational theory and earned more than normal subjects, who chose trying to avoid future regret.

References

Supporting Online Material
www.sciencemag.org/cgi/content/full/308/5726/1260c/DC1
SOM Text
Figs. S1 and S2
Tables S1 and S2
References
21 December 2004; accepted 3 May 2005
10.1126/science.1108099