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Why Too Much Interaction Between Different Parts of the Brain Leads To Unhappiness

Ricardo Alvarez, Yamel Hernandez, and Vladik Kreinovich

Abstract Reasonably recent experiments show that unhappiness is strongly correlated with the excessive interaction between two parts of the brain – amygdala and hippocampus. At first glance, in situations when outside signals are positive, additional interaction between two parts of the brain that get signals from different sensors should only reinforce the positive feeling. In this paper, we provide a simple explanation of why, instead of the expected reinforcement, we observe unhappiness.

1 Formulation of the Problem

General problem. Sometimes, we are in a good mood, and sometimes, we are in a bad mood. In some cases, our mood is determined by the external circumstances, but sometimes, a person who has everything is still unhappy. How can we make people happier?

To be able to do this, it is important to understand what brain processes cause different moods. If we learn why people become unhappy, we may be able to help them become happier.

This problem is very complex. The brain is a very complex structure, with many processes happening at the same time. Because of this complexity, until recently, it was not clear which brain processes are correlated with mood.

This complexity is also affected by the fact that the usual ways of studying brain activities – via Magnetic Resonance or other remote methods – provide information about the average activity of reasonably large groups of neurons, and it looks like this averaging filters out possible correlations – whose discovery probably requires more localized techniques.

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More localized measurements are available. The possibility to use more localized techniques of brain study comes from the study of epileptic patients. From the engineering viewpoint, epilepsy means excessive positive feedback, excessive amplification. Electric signals in the brain gets amplified – as they are amplified in all systems, to compensate for the natural signal decrease. The problem is that if this amplification is too high, the signal passing to and fro gets constantly amplified more and more – until it exceeds the safety limits and starts damaging the brain. This amplification is usually happening in one specific small part of the brain. To help the patient, it is therefore important to find the location of this area.

The brain is very important, we do not want to affect its functions, so we must pinpoint the defective area as accurately as possible. Such accuracy is often not possible if we only use non-invasive techniques. So, to help with this location, electrodes are implanted in several places in the suspected defect area, so that by measuring the corresponding brain activity, we will be able to very accurately pinpoint the defect area.

As a side effect, we also have a very localized description of brain activity.

A recent breakthrough. A recent (2018) study [3] analyzed this activity and found – for the first time – brain processes that clearly correlated with the person’s mood. Namely, it turned out that the person’s mood is determined by the interaction between two specific parts of the brain: amygdala and hippocampus.

Unexpected feature. The researchers expected to see how – directly or indirectly – signals related to external factors affect the person’s mood. This was indeed found. However, there was also an unexpected discovery – that for the same level of external signals, the mood was strongly affected by the degree of interaction between the above two parts of the brain: too much interaction between these two different parts of the brain leads to unhappiness.

Why? A natural question is: why? In this paper, we provide a possible explanation for this unexpected empirical phenomenon.

2 Analysis of the Problem and Resulting Explanation

Let us describe a simple mathematical model. Each part of the brain receives signals from our sensors, from different parts of the body, etc. Some of these signals are good – so they should lead to more happiness. Let us denote the overall level of positivity of signals coming to amygdala by $p_1$, and of the signals coming to hippocampus by $p_2$.

In general, different parts of the brain process different signals. The overall mood should depend on all these signals. So, it makes sense that there are interactions between different parts of the brain – that enable us to combine these signals and thus, get the signal reflecting the overall mood.

Interaction means that the signal coming from one part of the brain affects the signal in the other part. Thus, the overall positivity level $s_1$ at the amygdala is deter-
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mined not only by the signals $p_1$ coming to it from the corresponding sensors, but also by the signals coming to it from the hippocampus. The higher the activity level $s_2$ at the hippocampus, the more signals come to amygdala, so we can say that

$$s_1 = p_1 + k_{12} \cdot s_2,$$  \hfill (1)

where the coefficient $k_{12}$ describes the degree of interaction between these two parts of the brain.

Similarly, the resulting activity level $s_2$ of the hippocampus is determined not only by the signals $p_2$ coming to it from the corresponding sensors, but also by the signals coming to it from the amygdala. The higher the activity level $s_1$ at the amygdala, the more signals come to hippocampus, so we can say that

$$s_2 = p_2 + k_{21} \cdot s_1,$$  \hfill (2)

where the coefficient $k_{21}$ describes the degree of interaction between these two parts of the brain.

**At first glance, this cannot explain the empirical fact.** At first glance, it looks like our model (1)-(2) cannot explain the observed effect: based on the equations (1) and (2), the larger the degree of interaction between the two corresponding parts of the brain, the more positive will be the overall sense of happiness.

**A deeper analysis leads to the desired explanation.** Let us show, however, the deeper analysis of our model leads to the desired explanation.

Indeed, if we plug in the right-hand side of the formula (1) instead of $s_1$ in the formula (2), we conclude that

$$s_2 = p_2 + k_{21} \cdot (p_1 + k_{12} \cdot s_2) = p_2 + k_{21} \cdot p_1 + k_{21} \cdot k_{12} \cdot s_2.$$ \hfill (3)

Moving all the terms containing the unknown $s_2$ into the left-hand side, we conclude that

$$(1 - k_{21} \cdot k_{12}) \cdot s_2 = p_2 + k_{21} \cdot p_1,$$ \hfill (4)

hence

$$s_2 = \frac{p_2 + k_{21} \cdot p_1}{1 - k_{21} \cdot k_{12}}.$$ \hfill (5)

Similarly, if we plug in the right-hand side of the formula (2) instead of $s_2$ in the formula (1), we conclude that

$$s_1 = p_1 + k_{12} \cdot (p_2 + k_{21} \cdot s_1) = p_1 + k_{12} \cdot p_2 + k_{12} \cdot k_{21} \cdot s_1.$$ \hfill (6)

Moving all the terms containing the unknown $s_1$ into the left-hand side, we conclude that

$$(1 - k_{12} \cdot k_{21}) \cdot s_1 = p_1 + k_{12} \cdot p_2,$$ \hfill (7)

hence

$$s_1 = \frac{p_1 + k_{12} \cdot p_2}{1 - k_{12} \cdot k_{21}}.$$ \hfill (8)
When the interaction becomes too intensive, namely, when \( k_{12} \cdot k_{21} > 1 \), then even when the signals \( p_1 \) and \( p_2 \) are positive, the resulting states \( s_1 \) and \( s_2 \) – as described by the formulas (5) and (8) – become negative, i.e., indeed corresponding to unhappiness.

This explains the above-described empirical phenomenon.

**Comment.** From the mathematical viewpoint, this explanation is similar to a known explanation of another phenomenon – that an excess of empathy may lead to unhappiness – see, e.g., [1, 2, 4, 5, 6].

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