Biological Roots of Imagination

Living beings **anticipate changes** or **disappear.**

Anticipation

is the biological function of

Imagination

"**I think...** *Is this different from this ancient practice which consisted (and still consists) in consulting the "spirits"? Wait before a table, a deck of cards, an idol, or a dormant pythia, or before what one calls "oneself" ...*"

Paul Valéry - Bad thoughts and others - NRF Gallimard 1942. Page 24

Summary

Introduction

This presentation intends to show the **common features** between **biological imagination mechanisms** and some **methods implemented by the Dada and Surrealist** Art mouvements

This presentation is based on the works of FIVE Nobel Prizes in Physiology and Medecine Gerald Edelman -1972, Susumu Tonegawa -1987, John O'Keefe, Britt Moser, Edvard Moser - 2014

"**Surrealism, n.** : Pure psychic automatism, by which one proposes to express, either verbally, in writing, or by any other manner, **the real functioning of thought**. Dictation of thought in the absence of all control exercised by reason, outside of all aesthetic and moral preoccupation."

1.A - Localization & Anticipation in Mice

Place Cells

Grids Cells

Storage Optimization

Memory, Past and Future

Seeing in the Future

John O'Keefe - May-Britt Moser - Edward Moser
Nobel Prize 2014 (Physiology. & Medicine)

Place Cells - J. O'Keefe - Nobel Prize

In 1971, as he developed his research at Mc Gill University in Montreal, while recording the activities of individual nerve cells in the hippocampus in rats that were freely moving in a room, **John O'Keefe** discovered that **some nerve cells were active when the animal was located in a particular place in the room**.

He showed that the activity of these cells, which he called **Place Cells**, did not simply reflect what the animal saw but that they actually constructed **a map of the room**.

He concluded that **the hippocampus creates many maps of the environment**, each map being made up of all the cells that are active in a given environment. And so **the memory of a given environment can be stored into memory in the form of a particular combination of place cells activities** in the hippocampus.

Grid Cells - May-Britt & Edward Moser - Nobel Prizes

More than 30 years after J. O'Keefe discovery, May-Britt and Edvard Moser discovered another essential component of the brain navigation system.

While they were recording the activity of hippocampal cells in rats moving freely in a room, just as O'Keefe did, they identified surprising activities in another family of nerve cells in a neighboring brain area close by the hippocampus, the entorhinal cortex.

They named these cells, **Grid Cells**, and showed that **these grid cells constitute a system of coordinates which makes it possible to navigate through space**.

Grid Cells Activity builds up an Hexagonal Lattice

Unlike a **Place cell** in the hippocampus that activates at a specific location, activation of a grid cell in the entorhinal cortex **breaks down the surrounding space** and the grid cells together divide the surrounding space into **a regular hexagonal grid** that resembles the wax alveoli networks built by bees.

This breakdown is created by the brain, it does not pre-exist in the external environment, **it continues to occur even when the animal traverses a room in complete darkness**.

And May-Britt and Edvard Moser discovered that this hexagonal geometrical structuring that completely paves a flat surface without leaving any empty space, is created **by the brain**, **inside the brain** by the **activity** of the grid cells.

J. O'Keefe, May-Britt Moser, Edvard Moser
2014 triple Physiology & Medicine Nobel Prize...

Discoveries of **John O'Keefe**, **May-Britt Moser** and **Edvard Moser** revealed **two** essential and complementary **components** of the learning and memorizing of space.

A memory of the exact places where we once were, a form of autobiographical memory: the precise place where we were and the journey we made.

A topographic memory of the environment where we made our journey, that is inscribed on **a grid of hexagons,** as **a system of coordinates** allowing to **deduce the distances and the borders all around the place where we are**.

A memory of the map of places and a precise memory of our journey through these places.

Memorizing Neural Maps

Studies in mice that are on a route, indicate that each time they take a short break or stop to eat, **the film of the journey** they have just made, the succession of the different place cells activations **is displayed back again and again several times in an accelerated way** in their hippocampus : **the route they used** to reach that place **and the route back**.

The route they used to reach the place, is the film of the paths they have used to get where they are. And the way back is the film of the path that they would take if they had to go back to their starting point, that is, *if they had to escape*…

Later, **while asleep, the film of these successive maps will be repeated a greater number of times**, while being slowly **stored in the mice long-term memory, partly migrating into different areas of the brain cortex**.

Time compression...

The time component, the duration of the completed journey **is compressed, accelerated**.

A journey of several seconds is mentally redeployed in the much shorter time of a tenth of a second.

And the maps of the places traveled, which represent whole sections of the immensity of the outside world, are **reduced space re-compositions, pruned by numerous details**, a succession of tiny maps in the tiny inner worlds of the hippocampus and of the entorhinal cortex.

Storage Optimization…

How so many different maps of the places traveled can be drawn and co-exist alternately inside the hippocampus?

A response was provided by results published in 2011. The study indicated that, in the hippocampus, the type of a cell that participates in the elaboration of a map, may it be **a place cell** (activated) or **a silent cell** (not activated), is not fixed once and for all. **A cell that has become a place cell in a given environment can become a silent cell in another environment**.

The same cell can be part of the color ranges and of the contours of several different maps and also be part of the neutral background of several other maps. And this very large number of possible combinations enables the inscription and the persistence in the memory of **a very large number of maps of different places.**

Memories, Past and Future

But memory does not only tells us about yesterday, it also tells us about tomorrow. **Our memory allows us to imagine possible futures**. And **it is difficult to separate memory from imagination**. Complete lesions of the hippocampus that destroy the ability to acquire new conscious memories also alter the imagination.

To project ourselves in the future is always to appeal to the past. There is no crystal ball that would allow us to read the future, even the most rational, even the most scientific prediction can only be based on an extrapolation from what we learned and understood from the past.

> "*Are not you the future of all the memories that are in you? The future of a past.*" - **Paul Valéry**

And yet another Nobel Prize - S. Tonegawa

In 2011, a study by G. Dragoi G, and **S. Tonegawa** of the MIT involving mice revealed a strange relationship between memory and anticipation of the future...

Mice perform a route along an artificial trail that has particular topographic components...

When the mice arrive at the end of the first part of the route where the researchers placed food, they stop, eat, or fall asleep.

And **during their sleep, the succession of journeys they have just traveled is projected as a film repeatedly in their hippocampus, while beginning to register in their lasting memory.**

Seeing in the Future… (1)

This study identified an hitherto unknown phenomenon. When the first part of the traveled track ends with a gate that prevents the mice from seeing the rest of the course, during their rest, or sleep, **a series of apparently random variations** on these paths occurs. New, changing, open paths appear in their hippocampus.

As if, an anticipation of the invisible part of the journey was **invented**, an exploration of an imaginary and still unknown geography.
As if, a memorization of the future unknown part of the track was being prepared, a set of possible **pre-adaptations** to a still unknown topography, but which could share some common characteristics with places that had just been traveled.

"*Most of the thoughts we follow, opinion projects, etc., could be drawn lots* "- **Paul Valéry**

Seeing in the Future… (2)

For mice that had not taken any particular route during the day, the mere presence of the door at the end of a track that they had not traveled, induced **reactivating maps of probably old paths** and **building up variations on these maps**. These variations lead to the **emergence of about *fifteen* future journeys that mice have never yet used**.

The anticipation of a future move in a still unknown environment induced a recapitulation of the memories of past journeys and **a series of random variations** on these memories that allowed **a virtual exploration of the field of possibilities**.

So these probably **unconscious variations created during rest and sleep** on the theme of recent memory, and probably also on the theme of older memories, are probably **one of the forms of learning that prepares us for an unpredictable future.**

"But after all, reality is just a special case" **- Valéry**

Seeing in the Future… (3)

In May 2013, when the study of G. Dragoi and S. Tonegawa was published, another study was published in Nature by **Pfeiffer** and **David Foster** from the Department of Neuroscience at John Hopkins University in Baltimore,.

They had analyzed the activity of **place cells** in the hippocampus of mice, **not during their sleep, but during the moments before they began to go in a given direction** either to fetch food or to return to their shelter.

And they found that before engaging in a particular journey, **this path is prefigured in their brain before they start to use it**.

"*Forecasting is a dream from which the event draws us*" - **Paul Valéry**

1.B - Adaptive Immune System and Imagination

(A **VERY** Simplified Presentation of Adaptive Immune System Mechanisms)

Terminology…

Antigenes = our enemies (pathogens)

Antibodies = the marker proteins used to tag our enemies

In experiments beginning in 1976, Tonegawa showed that **genetic material rearranges itself to form millions of antibodies**.

Comparing the DNA of B cells (a type of white blood cell) in embryonic and adult mice, he observed that **genes in the mature B cells of the adult mice are moved around, recombined, and deleted** to form the diversity of the variable region of antibodies.

Preparing to identify enemies before they appear

The pathogenic microorganisms that our bodies have to face do not wear uniforms nor carry flags, and white blood cells that fight them have no eyes anyway.

In order to be destroyed, enemies must hence first be **identified** and **tagged**.
The number of types of potential pathogens is absolutely **huge**...

And yet **the body is able to produce in advance all the marker proteins needed to tag all past, present, existent and non existent and future microbes…**

The number of genes in the human genome **is quite small** (approx. 26,000). ***Not enough*** by far to encode the **billions of marker proteins** required **to mark pathogens. Millions of genes** would be needed **to store** such **a huge amount of information**.

Mechanisms of Genetic Imagination

A human being is able to produce nearly **a trillion** (10^{12}) different **marker proteins** (antibodies). ***How is it possible ?***

Part of the DNA of B and T lymphocytes is **fragmented** and then **recombined at random**, giving rise to a huge number of new genes capable of encoding billions of marker proteins (somatic recombination)

During their maturation, B and T lymphocytes are tested for their reactivity to characteristic molecules of the Self. B and T cells that react to molecules associated with the Self are **eliminated**. (prevents autoimmune diseases)

Use and Memorization of Proven Knowledge

Recognition of a pathogen by B or T lymphocytes induces 3 types of phenomena :

1 - **Tagging** of pathogens for their destruction by specialized lymphocytes

2 - **Clonal proliferation** (duplication) of lymphocytes that marked the pathogens (suddenly multiplied by 100 to 100,000 and further on)

3 - **Memorization** of the tagging in part of the B and T lymphocytes for a quick and efficient reaction to future similar infections (i.e. the very basis of vaccination).

The adaptive immune system **anticipates**. It "imagines", selects, uses and memorizes the knowledge acquired.

1.C - Common Features of Biological Imagination

Gerald Edelman Nobel Prize 1972 in Physiology and Médecine played a central role in discovering the mechanisms of the Adaptive Immune System

Gerald Edelman later founded and directed **The Neurosciences Institute**, a research center in San Diego that between 1993 and 2012 **studied the biological bases of higher brain function in humans.**

“ The way the components of the immune system evolve over the life of the individual is analogous to the way the components of the brain evolve in a lifetime. " - G. Edelman

Recombination of Fragments of Memories...

Mechanisms at the neuronal level (in the brain) and at the cellular chemistry level (in adaptive immunity) have ***similar features***.

In the brain, **fragmentation and diffusion** of memories during the building up of long-term memory, and later **random recombination** of these memory fragments are used to create **candidate anticipations**.

In the immune system, **fragmentation and random recombination** of part of the lymphocytes genetic **memory** are used to build up new genes allowing to generate marker proteins that are meant to **anticipate** recognition of trillions of enemies.

In both cases, **internal hazards** is systematically used to "imagine" and anticipate **external hazards**. In other words, **Life uses randomness as a source for imagination**

2 - Biological Imagination and Surrealism

Fragmentation and **Random Recombination** are the core mechanisms of

Collages

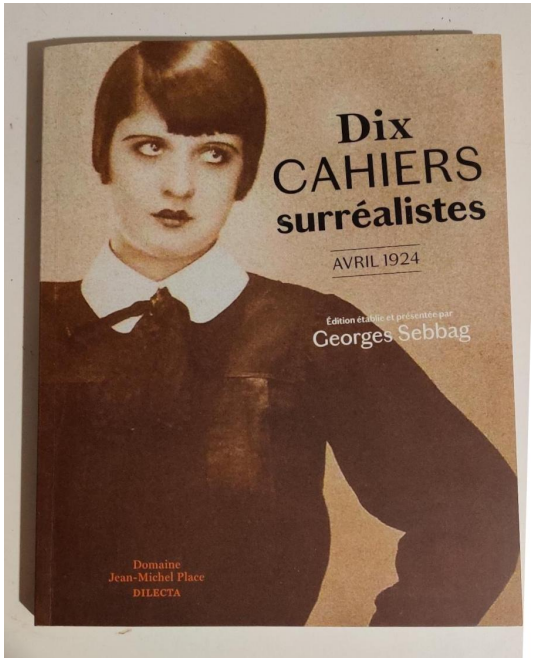
In April 1924, Breton distributed **school notebooks** to his surrealist friends
And they started a **Text Collage experiment**.

Results were re-published in 2020 by J.-M. Place and Dilecta publishing houses

10 cahiers surréalistes avril 1924 - Georges Sebbag - J.M. Place & Dilecta 2020

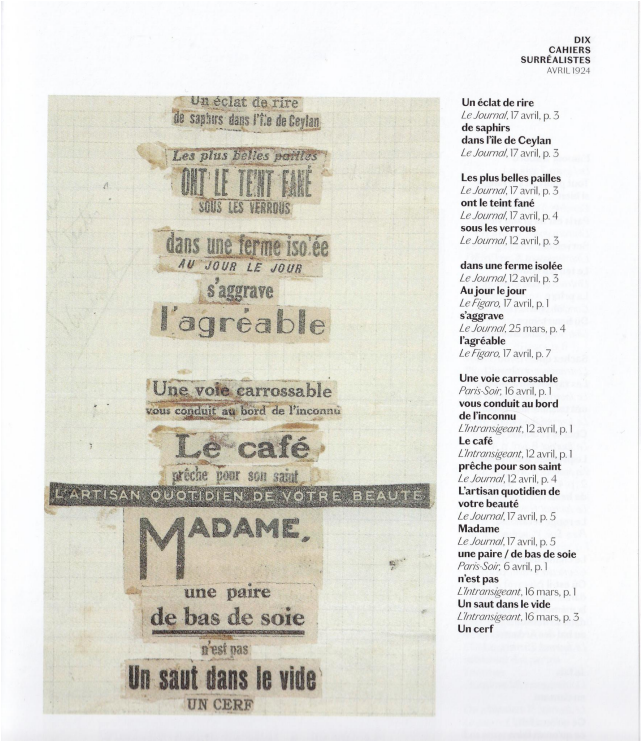
First notebooks created by the surrealists in 1924

Based on words and sentences cut from newspapers…



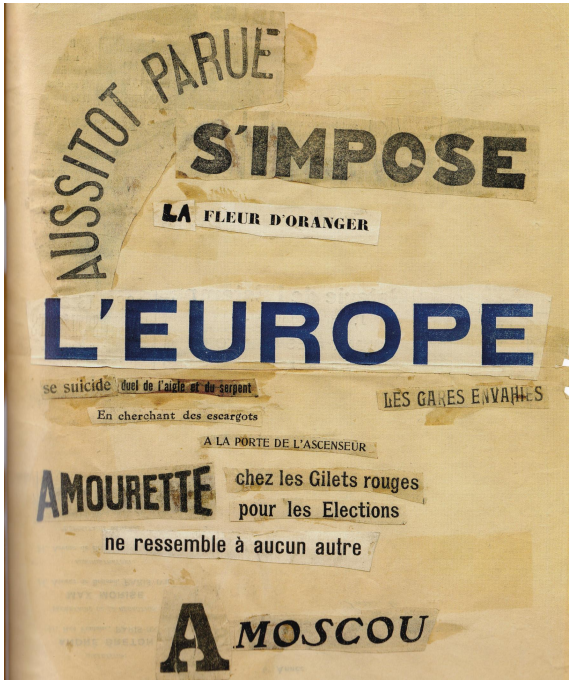
Recombining Bits and Pieces of Memories = Collage

André Breton - April 1924



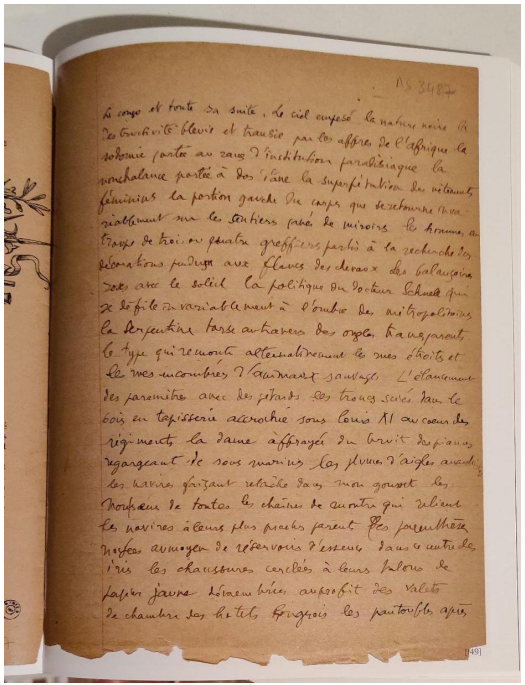
Recombining Bits and Pieces of Memories = Collage

Benjamin Péret - April 1924

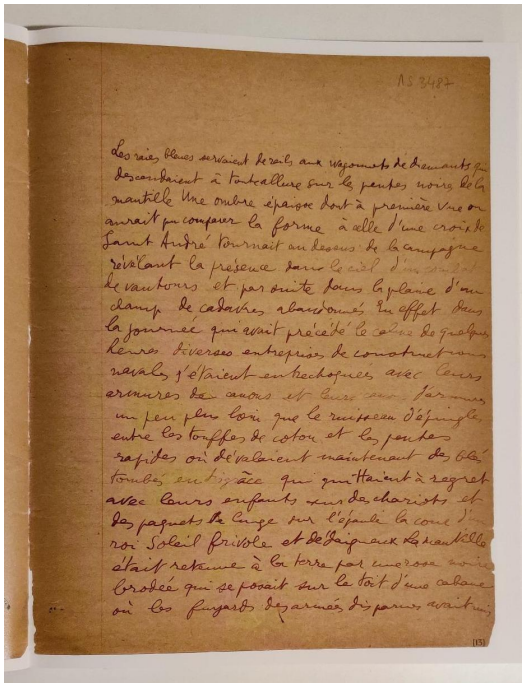


Automatic Writing…

Pierre Naville - April 1924

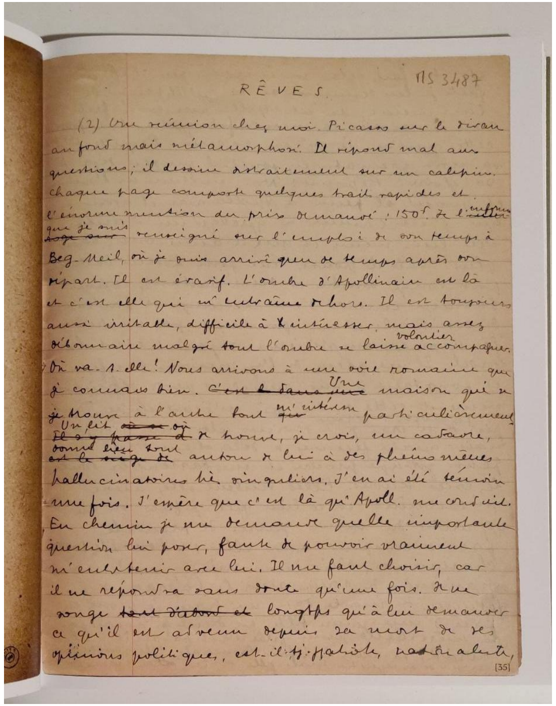


Louis Aragon - April 1924



Dreams…

André Breton - April 1924



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RÊVES

(2) Une réunion chez moi. Picasso sur le divan au fond mais métamorphosé. Il répond mal aux questions; il dessine distraitement sur un calepin. Chaque page comporte quelques traits rapides et l'énorme mention du prix demandé : 150f. Je l'informe que je suis renseigné sur l'emploi de son temps à Beg-Meil, où je suis arrivé peu de temps après son départ. Il est évasif. L'ombre d'Apollinaire est là et c'est elle qui m'entraîne dehors. Il est toujours aussi irritable, difficile à intéresser, mais assez débonnaire malgré tout. L'ombre se laisse volontiers accompagner. Où va-t-elle ! Nous arrivons à une voie romaine que je connais bien. Une maison qui se trouve à l'arche tout m'intéresse particulièrement. Un lit où se trouve, je crois, un cadavre, donne lieu tout autour de lui à des phénomènes hallucinatoires très singuliers. J'en ai été témoin une fois. J'espère que c'est là qu'Apoll. me conduit. En chemin je me demande quelle importante question lui poser, faute de pouvoir vraiment m'entretenir avec lui. Il me faut choisir, car il ne répondra sans doute qu'une fois. Je ne songe longtemps qu'à lui demander ce qu'il est advenu depuis sa mort de ses opinions politiques, est-il tj. patriote, nationaliste,

[35]

Writing is a Form of Collage

Just like in a collage, in writing, the meaning is not located **IN** the images themselves, but **BEYOND** the images :
in the way they are mentally assembled by the mind

3 - Temporary Conclusion...

Surrealism is not just Art...

Surrealism is **Life** !

Sources

Localization and spatial anticipation in mice :
Jean-Claude Ameisen - *Sur les épaules de Darwin* - France Inter (trans. P. Petiot)

Adaptive Immune System (and further..) :
Pour La Science (French version of Scientific American)
Wikipedia
Gerald Edelman (Nobel Prize) - Susumu Tonegawa (Nobel Prize)

Early Surrealist Collages :
10 cahiers surréalistes avril 1924 - Georges Sebbag - J.M. Place & Dilecta 2020

Hieroglyphs :
Source Wikipedia (thanks to Guillaume Blanchard)

Further reading

Rational Thought and Imagination (Bilingual book - P. Petiot)

https://www.lulu.com/shop/pierre-petiot-and-evi-moechel/rational-thought-and-imagination-pens%C3%A9e-rationnelle-et-imagination/paperback/product-r7v795.html?page=1&pageSize=4

Part one : The Method

(Was René Descartes really a rationalist ? Does “rational thinking really thinks ?)

Part Two : Biological Roots of Imagination (PDF)

https://www.web-pourpre.fr/LaBelleInutile/Site/2-Surrealism/2-Orientations/Pens%C3%A9eRationnelleEtImagination/Ressources/03-Racines%20Biologiques%20De%20L'Imagination/02-Racines%20Biologiques%20de%20L'imagination-En.pdf