Original Article

The Mechanism of Mourning
An Anti-entropic Mechanism

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Abstract
Mourning is a fundamental mechanism for our psychological dynamics. The mourning process attempts to transform an irreversible process such as the passing of time into a reversible one, where the moment of loss is re-enacted and elaborated. In thermodynamics the inevitable increase of entropy for every complex system makes it impossible to invert the direction of time. However our brain, via the mourning, is performing such a time inversion. This paper explores the conditions under which such a process is possible and the implications in terms of entropy of considering thoughts as physical objects. A possible formalisation of this process is suggested using the formalism of chaos theory, as it probably presents a very high degree of nonlinearity.

Key Words: chaos, mourning, psychodynamics, time-reversal

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Introduction

We can imagine our brain as a "thinking device" to organize ideas, sensations, perceptions, affects and to put order into them. If we consider the definition of entropy as a "measure of disorder" it could seem that we are indeed machines specialized at operating in opposition to "natural laws", according to which entropy tends to increase and it is maximum at equilibrium: because of an intriguing form of disobedience, not strictly human, against

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"natural laws", life is the phenomenon of passage from simple atoms to complex animals.

The concept of Kolmogorov-Sinai (K-S) entropy, which increases with the information content, provides a model to reconcile the human, and generally life's, tendency to order with the inevitable increase of entropy.

Perhaps it is also not entirely casual that we are forced to use two different definitions for entropy. On one side the thermodynamic entropy, maximal at the equilibrium for non dissipative systems, and on the other, the K-S Entropy for dissipative systems, minimal at the regular attractor, which for dissipative systems is the equivalent of the "point of equilibrium", and diverging to infinite for "strange" and "chaotic" attractors.

As it is subject to the irreversibility of time, life has deployed a strategy of cyclical repetition. As time passes, we advance trough seasons, days and nights. Everything repeats in a continuous return that fosters our illusion to come back to past.

On the other hand life, via the human mind, has invented, at least in first approximation, an "absolute and certain" knowledge, independent from the passing of time.

About absoluteness

It is interesting to recall what Henry Poincaré wrote already in 1908:

> "A very small cause, which escapes us, can produce a considerable effect that we cannot ignore, and then we say that this effect is due to chance. [...] It can happen that small differences in the initial conditions generate large differences in the final state. A very small error on the former will produce a very large error in the prediction of the latter. Forecast becomes impossible and we have a random event".

In 1919 two French mathematicians, Gaston Julia and Pierre Fatou, used an iterative method, invented by Newton, to find the zeros of a non-linear function with complex numbers. Gaston Julia and Pierre Fatou used this method with functions of varying regularity, and among those some were converging to determinate values and others diverged toward infinity. At the time, the possible implications of this interesting work were not apparent.

Since the 1950' a special attention has been devoted to this discovery thanks to the power offered by computers to numeric intensive computation experiments. Edward Lorentz was the first scientist who, thanks to computational experiments, had a glimpse of chaotic phenomena. He made the discovery that a small difference in the initial conditions can result in a huge difference in the results. He also discovered chaos attractors in the phase space that are points where information and dimensions are reduced and entropy increases.

Benoit Mandelbrot later resumed these studies when computing power finally allowed results to be "seen". Mandelbrot could draw in black the points where the successive iterations of the Newton method do not diverge after thirty repetitions, leaving white the divergent points. The shape drawn in this way had the property to repeat the same pattern at each point. He illustrated in this way the spontaneous creation of organized structures emerging from the disorder, the fractals.

It is revealing that Poincaré was extremely reticent to accept Cantor's theory of infinities. On this subject he decided that future generations would have regarded this theory of infinities as an "illness from which we recovered".

Notwithstanding, it had been Poincaré himself who demonstrated the non-integrability of the motion equation for the three bodies problem, which amounted to renounce to a formally closed description of reality.

George Cantor, has been the founder of the theory of transfinite numbers, of which he expressed the order and the power. The Cantor set seems to express a fundamental principle of the natural order. Indeed, for the dissipative systems it plays a fundamental role in the description of chaotic attractors. We can suppose that during his life he had reorganized his escape toward the loss of limits in his mind via a technically revolutionary formalism.

Stating that the mathematics is totally free and those concepts only have to obey to the non-contradiction principle, Cantor gained the possibility to invent several infinities, and he distanced himself from the sacred and understandable "naturalness" of the natural numbers. Unfortunately Cantor became psychotic and ended his days in a psychiatric hospital.

Ludwig Boltzman questioned, from another perspective, the relation between the behaviour of atoms and molecules and the properties of matter, answering in statistical terms to the problem of the link between microscopic and undetectable on one side and macroscopic and measurable on the other. Boltzman, poorly understood by his contemporaries and ill, killed himself at Duino on October 5, 1906, shortly before the experimental verification of his theories.

In the subject of quantum mechanics, Heisenberg has, so to speak, organized, or sublimated, the problem of his "distance" from the people en general by his theory of indetermination.

In spite of his marriage in 1937 and his large family, who offered him, in his own words, a great stability, he recalls the period around 1939 as very difficult both personally and politically and as a moment of "infinite loneliness". The difficult situation in his affective life may have made apparent to him the impossibility to control at the same time all the parameters of existence, together with the fact that life is governed by uncertainty and that the actors of existence, in the affects or in the reality, maintain between them an insurmountable distance (Cassidy, 1991). Far from being without method, chaos seems to have a fractal structure, both assuredly deterministic and unpredictable. This structure repeats at different scales an unexpected regularity, following the structure of the chaotic attractors. Moreover the formalism of deterministic chaos, which describes the dissipative phenomena, seems to be more adapted to nature than the classical models, both relativity and quantum mechanics, which describe limiting conditions. This can constitute an occasion for reflection on the link between exact sciences and the psyches of the "founders" of our knowledge of reality (and our own psyches after all). The concept of chaos that Newton would have certainly disdainfully excluded from his description of nature and from his absolute model comes back to us effectively thanks to the recursive method he invented to find the zeros of a function. Via successive iterations we can approach the value of the variable where the function is zero, if the function shows a sufficient regularity. At the very heart of the formal beauty of classical physics and Newtonian mechanics hides the mathematical treachery of the recursive method, the fractals and finally the chaos.

It is as if, via the effort of translation of reality into the physical model, physicists and mathematicians ambiguously spoke of their inner world, including their dreams and their fears. We could even suppose that the stricter is the logical frame the more the theory that develops within its boundaries openly shows the underlying affective roots that have generated it, as a dance of fish under an ice layer (Bournier, 1962).

Thoughts are physical objects?

We could say that the more life becomes self-conscious and capable to defend itself, the more it is able to approach self-knowledge.

In this sense it is possible that the development of our model of the physical world has followed the "internal models" of those who contributed to it, often unknown to themselves (Carminati, 1996; Carminati, 1997) so it is perhaps not a mere chance that one of the fathers of classical physics, Newton, was at the origin of the recursive method which in our century has opened the way to the modellisation of chaotic phenomena.

The mathematical and/or physical and/or physico-mathematical models describing physical objects could be considered as a production of our mind and this is fortunate because our mind is in fact a physical object. It is interesting to note that so-called physico-mathematical models, borne in our mind, fit so nicely with the observed universe.

The description of our mental state will be given by a complex-valued function $\Psi(X,Y,Z)$ belonging to a Hilbert space of functions with summable square (L^2). According to the definition of the Hilbert space, these functions will form a vector space with an inner product given by

$$\langle \Psi | \Phi \rangle = \int \Psi^* \Phi \, dV$$

where the integration is over the entire variable space, to be defined later. In our model X is the variation in time of the flux the thought (see later). The other coordinates are Y representing the granularity of the mental state system and Z representing the mood, by definition hot mood at the top and cold mood at the bottom. We mean hot as accelerate (fast) mood and cold as quiet (cool) mood.

Furthermore we make the hypothesis that these three variables are linked by the non-linear system of equations described below.

The coordinate vector or number could describe also the thoughts thinking the coordinate vector or number, but also (why not) affects, moods, words and so on. We can utilise this system of equations to determine the flux of thought. We supposed that the evolution of X, Y and Z, given suitable initial conditions describes the evolution of our thoughts.

$$\begin{aligned} \dot{X} &= -\sigma X + \sigma Y \\ \dot{Y} &= rX - Y - XZ \\ \dot{Z} &= -bZ + XY \qquad for\, \sigma, r, b > 0 \end{aligned}$$

The reader will recognise the classical Lorenz equation describing the laminar flux of a fluid, the system described is dissipative. Mental states evolve in time along trajectories in a three dimensional space given by these three coordinates.

These equations contain three parameters: the Prandtl number, the relative Rayleigh number *r* proportional to the applied temperature difference *T* and the geometrical measure *b*, derived from the geometry of the conduction cell.

This set of equations has a known chaotic behaviour for some sets of the constants, *r* and *b.* In this case, the trajectories cluster around a strange attractor with two unstable fixed points that are the foci of the saddle of the trajectories. This system, called the Lorenz system displays chaotic behaviour in time while the spatial pattern of the phase space is globally ordered.

Now we take our thought fluid described by the Lorenz equation and we decide to define as a function of *X*, *Y*, and *Z*, i.e. a function of variation with time of the flux of thought, granularity and mood and we have:

$$\bar{I}(\varepsilon) = -K \sum_{i=1}^{W(\varepsilon)} p_i(\varepsilon) \ln p_i(\varepsilon) \qquad K = \frac{1}{\ln 2}$$

Where *W(ε)* is the number of hypercubes of edge length required to cover the attractor.

We consider now the H as the partitioning of the variable space in M(ε) cells H_i of typical dimension which is our measuring precision. If we consider an initial point x_0 at the time t_0, the evolution of the system can be exemplified by the successive positions of this point x_n at times t_0+n t. Given the finiteness of the precision of our measuring device, this is in fact a succession of cells H_i^n. Given that the transformation that describes the evolution of the system is deterministic, we can determine from which *portion* of cell H^0 the point should have come if at time t it is in H^1:

$$H^0 \cap \Phi_{-\Delta t}(H^1)$$

If the probability to be located in cell H^0 was p^0 the probability to be located in cell $H^0 \cap \Phi_{-\Delta t}(H^1)$ will be no greater, i.e. information will increase because we can determine positively a less probable fact thanks to a second measurement. On the other hand our point now has been in two cells, so the system is less "ordered" and it is intuitively correct to suppose that the entropy has increased too. In order to generalise the treatment, we can consider all the possible combinations of a point being in cell H_j at time t_0 and in cell H_k at time t_0+ t. This gives us a space $S^{(1)} = H \otimes H$ so that:

$$S_{i,j} = \{x \in H_i \cap \Phi_{-\Delta t}(H_j)\}$$

The new information content of the system will be

$$\bar{I}(S^{(1)}) = -K \sum_{i,j=1}^{M} p(S_{i,j}) \ln p(S_{i,j}) \qquad (1)$$

and the sum now extends over M^2 cells. This procedure can be repeated for the subsequent evolution of the system:

$$S^{(n)} = H \otimes \Phi_{-\Delta t}(H) \otimes \Phi_{-2\Delta t}(H) \otimes \ldots \otimes \Phi_{-(n-1)\Delta t}(H) \otimes \Phi_{-n\Delta t}(H)$$

so that the information gain during the evolution of the system is its K-S entropy *h* and it is then defined as the upper limit of the average information gain per unit time produced by the dynamical system (Argyris, 1994):

$$h(\mu) = \sup_{H,\Delta t}\left(\lim_{n\to\infty} \frac{\bar{I}(S^{(n)})}{n\Delta t} \right)$$

where =*f(X,Y,Z),* in which we remember that we define *X* as the variation time of the flux of thought, *Y* is the kind of granularity of the system and Z the mood (by definition hot at the bottom and cold at the top).

It is important to note that the upper limit is taken for all possible initial partitions and all possible measurement intervals and that is the invariant natural measure of the system giving the density of points or trajectories, in our case coordinates of thoughts.

To explain briefly the concept of K-S Entropy, we have to remember that Kolmogorov and Sinai, in 1958, introduced this concept to quantify the degree of disorder, the degree of our ignorance of the system, and thus enable us to state the fundamental limits of the predictability of a dynamic system. We can say, also, that K-S Entropy measures the transfer of information from the microscopic to the macroscopic scale. The point is that a system with a fine granularity provides a lot of information but, following the definition of K-S entropy, it increases its entropy. Here is some paradox, because a large increase of the granularity that could appear as a very ordered system increases the information but increases also the entropy.

The mourning mechanism: a paradigm.

The model of an absolute and symmetric space-time has been all but ineffective: science and technology, but also philosophy and arts have progressed thanks to the search and adoption of absolute models, where space and time were universal and everything was symmetric with respect to time.

Symmetry in the description of a physical system has its root in the symmetry in time, which materializes in the presence the "invariant of motion": in some sense a system, both in classical and in quantum physics, cannot be described without this form of time independence (see **annex I**).

Time behaves differently from the other physical quantities. In quantum physics it is not a real operator and it does not have an average value, it is a somewhat marginal quantity. It is remarkable that when used in the solution of physics problems, it loses its major feature: its unidirectional flow (see **annex II**)

The concept of symmetry, largely used in classical and quantum physics, does not have a straight application in the dissipative phenomena. Also the concept of equilibrium is different for dissipative and non-dissipative systems.

The passage from a non-dissipative model, time reversible and without energy dissipation, to a model where the description of the events does not limit time irreversibility to the macroscopic world, marks a philosophical transition from a model which should be "perfect and absolute" to a model where the description of reality is "imperfect by definition".

From the psychical viewpoint, there exists a mechanism that is analogous to the concept of symmetry in physical and mathematical models and this mechanism is that of mourning. Even if the mourning presents some limits that are intrinsic and known by our human experience, in spite of the imperfection of the process, we cannot deny the attempt to repair the loss and the reorganization of the psychical system through it.

Thus the mourning process is an affective mechanism of great interest, both for its usefulness and for its intrinsic imperfection. Complete reparation is never possible even when the "granularity" of the system is so small that it allows a highly effective repair processes. The mechanism of mourning is a psychical device, a model to describe and understand the structure of the psychical system.

So we could say that, thanks to symmetry, the physical laws valid in a given system will, via appropriate transformations, be valid also in another system. With mourning we try to make a psychical system work after a loss, which is itself a transformation, real or imaginary.

Now, we could suppose to use the mechanism of mourning as a paradigm.

Archaeologists seem to agree to identify in the care for the dead body, that is the capacity to establish a ritual for the transition to death, the first step toward civilisation. Moreover the fact to allow some members of a community to attend to the necessities of the funerary ritual, and be exonerated from the quest for food, indicates the presence of a social structure with different tasks.

The reaction to a loss can be considered as an attempt to repair the loss of a member of a community and to face the ineluctability of time. It could be interesting to compare the individual mourning to the group mourning but this is not the subject of this paper (Carminati, 2002).

In all the passage rituals the loss of something is marked by the gain of some other entity. Thus in the yearly rituals, such as the end of winter, the propitiation of the harvest, the winter solstice or the coming of a messianic person, the coming of every period of the year corroborates the eternal circular cycle, both in the time and in nature. In this sense the mourning, as other passage rituals, reproduces the "natural model" of cyclicity.

The more a civilization feels able to withstand the course of time, via a technology that can reduce accidental death, for instance a social organization avoiding poverty or a medical system increasing life expectancy, the more the passage rituals lose their repairing feature. Mourning becomes a problem of personal loss and the mourning mechanism becomes more intimate.

But also, in the today world of intimacy, more than rituals the mechanism of searching, changing, repairing, in other words the mechanism of over-coming the loss, can represent an anti-entropic mechanism of re-organization and re-complexification of the mental world.

If we rather believe that the psychical system is dissipative, suffering a loss of energy, the mechanism of mourning will be imperfect, by definition the time will be irreversible, and the entropy, in any case, will increase, even if slowed by the anti-entropic tendency of the mourning. The concepts of dissipation, loss of energy and irreversible time, are thus appropriate to describe the psychical system, coping with loss and trying to regain the previous situation "*ante perditam*", in other words before loss.

If we suppose that the psychical system is without dissipation, we shall find the definition of a "without time" perfectly logical and we could be lead to imagine the mechanism of going back completely efficient.

But our memory, lacking infinite capacity and precision, will inevitably produce an imprecise positioning at the moment of the loss. Even if we decide to follow a non-dissipative model, and if we define the psychical change as the conjugate quantity to psychical position, we may conclude that the repair process has a minimum "granularity" beyond which it becomes impossible.

Starting from the difficulty to define the psychical situation at the moment of the loss, acting simultaneously to the psychical change, we could define the minimum "granularity" as the maximum achievable simultaneous resolution of psychical positioning and change, using here the concept of uncertainty of quantum mechanics.

"Granularity" could be also defined, in analogy to the resolution limit in optics, as the minimum distance between two points, in our case two psychical events, below which these two points, or events, blend into each other and cannot be "precisely distinguished".

We want to precise that, applying a dissipative or a non-dissipative model, we meet in both cases a similar problem of "imperfect positioning" of the event or "imperfect repairing" of the loss, because the separation of two object (position or change) cannot be precise enough or because two operators (position and change) cannot work precisely enough to obtain a complete "*restitutio ad integrum*" (return to integrity) of the system. We could suppose that this lack of information because of limited resolution prevents K-S entropy from becoming infinite. The point is that the non-dissipative model uses here the definition of K-S entropy that belongs to the dissipative model.

More verbatim words even if we avoid the decision about the "good" model to choose, non-dissipative or dissipative, in both the models the "operator of position" (memory) and the "operator of change" (disinvesting and reinvesting) cannot work together to attain the "perfect reparation" of loss.

We could describe the mourning, or rather the coordinates of thought working in the mourning, as moving around a Lorenz attractor. If we want to use a dissipative model the arrow of time is "naturally" decided (Prigogine & Stenger, 1998; Prigogine, 1996; Penrose, 1990). If we decide to use a non-dissipative model, even if time-symmetric, we will be obliged to order the direction of thoughts in the description of the mourning.

If we introduce the operator of probability:

$$P(V_\varepsilon) = \int_{V_\varepsilon} \Psi^*(X,Y,Z)\Psi(X,Y,Z)\,dX\,dY\,dZ$$

That is

$$P(V_\varepsilon) = \langle \Psi | \Psi \rangle \big|_{V_\varepsilon}$$

We can express the $\bar{I}(\varepsilon)$ previously introduced (1) as

$$\bar{I}(\varepsilon) = -K \sum_{i=1}^{W(\varepsilon)} P(V_\varepsilon^i) \ln P(V_\varepsilon^i) \qquad K = \frac{1}{\ln 2}$$

$$-K \sum_{i=1}^{W(\varepsilon)} \langle \Psi | \Psi \rangle \big|_{V_\varepsilon^i} \ln \langle \Psi | \Psi \rangle \big|_{V_\varepsilon^i}$$

About the granularity of the psychical system

In a well-structured psychical system we have a conformation and distribution of affective investments that can be compared to a well ordered hive: a "small cells system".

This organization of the psychical system and its distribution of investments suppose good conflict-management capabilities because levelling requires a mixing of energies and therefore the ability to accept the presence of multiple and contradicting tendencies. In the very process of mourning, after focusing on the loss, it must be possible to accept, for instance, the contradicting affections between the love for an object and the hate for the same because it has been taken away from us.

The "small cells" system remains a system of limited, but well organized exchanges, as it is characterized by a large redistribution of investment.

The positioning is easy and the process of disinvesting will be therefore small and manageable. Consequently the reinvestment of other psychical objects is easier, although never coming back to the "*ante perditam*" state.

We could consider, as an example at the other extreme, a much less structured system: the "dam system". In the "dam system" the structures are less detailed, with large areas of common investment for different psychic objects. Here the focusing will be quite less effective, and the disinvesting will engage a "larger location" of the psychical system. This emotional invasion might have a destructive outcome on the structure of the system and be at the origin of a traumatic state that could be compared to psychical illness.

We remember the definition of K-S entropy noting that a dam system, very low in information, that is a primitive system has a low level of information and a low level of K-S entropy and a hive system, high in information, which can be defined as a sophisticated more evolved system, has also a high entropy. In other words the thinking machine of our brain produces information and K-S entropy.

Using equation (2) we remember that the sum now extends over M^2 cells. This procedure can be repeated for the subsequent evolution of the system:

$$S^{(n)} = H \otimes \Phi_{-\Delta t}(H) \otimes \Phi_{-2\Delta t}(H) \otimes \ldots \otimes \Phi_{-(n-1)\Delta t}(H) \otimes \Phi_{-n\Delta t}(H)$$

in which H is considered as the partitioning of the variable space in M(ε) cells H_i of typical dimension which is our measuring precision.

So that the information gain during the evolution of the system is its K-S entropy *h* and it is then defined as the upper limit of the average information gain per unit time produced by the dynamical system:

$$h(\mu) = \sup_{H,\Delta t}\left(\lim_{n\to\infty} \frac{\bar{I}\left(S^{(n)}\right)}{n\Delta t} \right) \quad (3)$$

We can calculate the $h(\mu)$ in a system with large dimension of ε, where we will obtain low value of $h(\mu)$ and with small dimension of ε, where we will obtain high value of $h(\mu)$.

To visualize the different outcome of loss, we can imagine than when a "small cell" is lost, the reorganization of the system engages a mechanism of finding and repairing on a performing structure (performing in the organization of memory and in the distribution of investment).

However, the effective superiority of a well-structured psychical system to manage the event of a loss is penalized by its inability to operate large energetic exchanges. In both these cases, as well as in the intermediate ones, the psychical system will tend to re-balance the distribution of investments.

The psychical system reuses the best it can its structure and its energy to soothe the uncomfortable feeling caused by the loss, trying to come back to a situation "quo ante" (as before), without ever reaching it. In a less structured system, the loss triggers an energetic earthquake, and the psychical system can be confronted to a traumatic state, needing a large restructuring of the system in its totality.

A psychical system not able to accept the conflicts chooses high barriers to avoid contrasting, more detailed, differentiated and intricate investments, manageable but expensive in entropy. Faced with the loss of an invested object, it will use denial, separation or projection to shield from the contrast and conflicts and this barricaded system will be very unmanageable.

When a psychical earthquake makes the symptoms too important and/or dangerous to the state of a patient, there is, in principle no doubt that an attempt at a better redistribution of the psychical energy becomes advisable. However, a forced dumping of the earthquake can flatten or make infeasible the investment on a psychically plausible object and could prevent any psychical evolution to a more original (but more uncertain) path, privileging a greater conformism in the choice of the objects to be invested.

Perhaps for an excessive need of efficacy (or schematization) the attention of the therapist is often addressed too much and too quickly to the overcoming of the symptom rather than to the analysis of the psychical evolution (above all when a clinical emergency is present).

A psychical structure is the result of a quite long evolution of the individual, and this evolution depends on his genetic, somatic, psycho-dynamic and environmental context. Moreover, we have to admit that every form of therapy dealing with the investments of psychic objects can highlight the same mechanisms engaged in the mourning and therefore re-actualize the mourning (and the loss) (Abraham, 1993 and 1994; Vicario, 1973; Tschacher, 1996).

In other words the mechanism of mourning is a psychical device of the individual and every therapeutic approach mobilizing the psychical system, although providing an irreplaceable instrument of observation of the psychical structure of the individual, will necessarily evoke a loss and stimulate an imperfect repair.

Conclusion

The need for reparation via understanding and reinvestment is shared with our physical-mathematical models of nature and in this sense the mourning could be considered strictly correlated with formal models expressed in mathematic language.

The imperfection of the mourning mechanism is marked by the curse of loss: the inevitability of death is psychically (and only partially) repaired with the mourning mechanism.

We could bring further the parallel between the symmetric model in physics and the mechanism of mourning: the mourning mechanism attempts to repair the "false note" of the loss/unidirectional time reorganizing the psychical system but the mechanism of reparation in imperfect, as imperfect is the mechanism of life.

Even the attempts to understand nature could be considered a challenge "going in the direction of life" through the organization and making more complex the models. Starting from a state of simple organisation this can be considered a move to a higher level of knowledge (and of entropy too). The interest of the mechanism of mourning as a model resides in the possibility of an advanced formalization using the parameters of loss and of the psychical structure.

We hypothesize that a more formal approach to psychical events, without necessarily importing terms and language "*prêt à porter*" (of the shelf) of another science, could help the comprehension of the psychical functions and could open a new horizon for their study.

Annex I

Symmetry has been one of the technical artefacts with which modellisation problems have been solved. Using perturbation theory, for instance, we consider the symmetric Hamiltonian as the unperturbed one, and the non-symmetric contribution as a perturbation. In the last century, Sir W.R. Hamilton, a Dublin mathematician, invented this formalism to designate the path that contained once and only once the top of a graph. Successively physicists found its use convenient and they used it to describe physical phenomena. The symmetry properties of a physical system, which is the invariance of the physical laws that describe it, depend on the invariance of the Hamiltonian operator under appropriate co-ordinate transformations. Let us mention few examples: the Lorentz transformations guarantee the invariance of Maxwell's laws between inertial systems, while Gauge groups express local field invariance and phase transformation express invariance properties of quantum fields. When an operator does not depend explicitly on time and, moreover, it commutes with the Hamiltonian, the quantity of the physical system that it describes is indeed a constant of motion. By commutation we mean a property of two operators of yielding the same result if one is applied to a physical system before or after the other (not in fine but formally). The operators that constitute the Hamiltonian have the feature of being constant in time, and, on the other hand, the Hamiltonian itself that describes the time evolution of the physical system is constant in time. In classical physics the Hamiltonian represents the total energy of the system, while space and time are absolute entities. In relativity, where particles are tiny, very fast and numerous, these entities lose their absolute character and it is the speed of light that becomes constant. The Hamiltonian itself changes of nature, thanks to the plasticity of the differential formalism, evolving from the result of an equation into the operator of the equation itself. In quantum physics the Hamiltonian thus becomes the operator that describes the variation in time of the physical system, and the eigenvalue of the system is indeed the energy of the system. Position, momentum and energy take up the role of operator of position, operator of momentum and Hamiltonian and determine their eigenvalues, which are the corresponding physical entities. Position and momentum on one side and energy and time on the other are pairs of operators and they determine conjugate quantities (with the limitation that we see for time), therefore their operators do not commute and the corresponding physical observable quantities cannot be known at the same time with arbitrary precision. In the solution of physical problems often the stationary solution is sought, that is the solution that does not depend on time. To free the description of a physical event from the dependence on time is one of the conditions requested to the physical and mathematical model. When an operator is applied, for instance, to a wave function in order to find the corresponding physical state, the time dependence is avoided by taking a fixed time. As far as time is concerned, there is no real operator that corresponds to it outside very restrictive conditions, including the commutation with the Hamiltonian. The problem with time is that, contrary to other operators, it does not have an average value in a given system.

Annex II

Let us introduce the time-ordered operator T, working on *thought coordinate* Ψ *,* as

$$T\{\Psi(X,Y,Z),\Psi(X',Y',Z')\}=\begin{cases}\Psi(X,Y,Z),\Psi(X',Y',Z') & \text{if } t>t' \\ \Psi(X',Y',Z'),\Psi(X,Y,Z) & \text{if } t'>t\end{cases}$$

The $\Psi(X,Y,Z)$ operators operate with a defined order.

$$\vartheta(t)=\begin{cases}1, & \text{if } t>0 \\ 0, & \text{if } t<0\end{cases}$$

$$T\{\Psi(X,Y,Z)\Psi(X',Y',Z')\}=\vartheta(t-t')\Psi(X,Y,Z)\Psi(X',Y',Z')-\vartheta(t'-t)\Psi(X',Y',Z')\Psi(X,Y,Z)$$

So the $(\Psi(X,Y,Z)-\Psi(X',Y',Z'))=\langle 0|T\{\Psi(X,Y,Z)\Psi(X',Y',Z')\}|0\rangle$ (Mandl, 1984)

ordering the $\Psi(X,Y,Z)$ and the $\Psi(X',Y',Z')$ operators.

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