On the constitution of the concept of space out of the causal structure of the subject's world

Silvère Gangloff

June 12, 2022

I have formulated earlier[1] a question which I believe is of fundamental interest for understanding how the mind relates to matter: *since the human mind can in principle simulate any possible computing machine (as defined by A.Turing), how may the human brain make possible this simulation ?* The interest of this question lies in the possibility, through a meticulous form of introspection, to construct some hypotheses on how the mental simulation is related to the functioning of the brain.

The purpose of the present text is to extend this approach to another question whose answer - or attempts to answer - should provide other insights into the relation between mind and matter: how does the human mind constructs a mental model of space, and how does it validate this model - judging that this model is indeed a good representation of space ? In this question, I use the term '*space*' in order to designate the space $\mathcal{I}$, as a subject, am '*in*', and the model of space refers to the mathematical concept of *tridimensional euclidian space*. It should be pretty clear that it is possible to conceive the space $\mathcal{I}$ live in without having formed in my mind this concept of space, thus we can and shall consider them as separate entities, and the relation that tie them is a mental construction that we shall explain. It should be in principle possible to extend this question to other concepts of space such as the one of general relativity, but in order to develop a method in order to answer questions of the same type it is necessary to focus on a simple case. Furthermore, because of the nature of this question, whether we should think of the '*physical space*' - whatever this means - in euclidian terms or the ones of general relativity is not relevant, for the reason that this physical space is not the object of interest here but rather the *conceptualization* of space. Ultimately, one may also wonder how the judgment that $\mathcal{I}$ am in a space at all is constructed: instead of placing this question at the center of the investigation, I shall consider any accidental answer to it as a marker of understanding for the constitution of the concept of space.

The interest I have for the conceptualization of space comes from two questions related to mind and matter: **(i)** Is it possible to think of the mind as spatial ? For instance it is possible in principle to define the distance of a men-

[1] **S.Gangloff**, *Creative introspection and the structure of the experiencing subject*

tal content - not actual but potential - to me as the difficulty for me to actualize it in my mind. The fact that the actualization of a mental content sometimes implies beforehand the actualization of another one let us see that there are possible *ways* of actualization. The mind, in a sense, has a spatial *structure*. However it is naturally difficult to attempt frontally to understand this structure: in this direction, a relatively precise formulation of how the concept of the space $\mathcal{I}$ am in is formed would be of interest, for one could 'apply' it to the spatiality of the mind. **(ii)** The second question follows and at the same time constraints the first one. One possible way to integrate the '*observer*' in physics is to think of the mental space and the '*physical space*' as parts of another space which contains both. The question is the following: how may these two notions of space be integrated into a third one ?

——— An ontology based on space analysis constructions ———

I have already written[2] some critics against the approach of the concept of space proposed by A.Haun and G.Tononi[3] in the framework of *Integrated information theory*, based on particular way they combined philosophy and mathematics in this work. Here I would like to criticize it as an approach of space as it is felt from the point of view of a subject, in order to depart from it and introduce another one which I believe is more faithful to its phenomenological nature.

1. *Outline.* — In a nutshell, the approach proposed by A.Haun and G.Tononi consists in constructing a detailed correspondence between grid-like neural networks which are related to the cognitive processing of spatial aspects of experience and the spatiality of experience. They propose that areas that are distinguishable in the perception field - that they call '*spots*' - may be assimilated to groups of neurons in a certain state in the grid-like neural networks, where the parameters defining the relations between the neurons evolve in time - and as a consequence the 'presence' of these areas may also evolve according to these parameters. The reason why one distinguishes at a moment one particular of these areas at a time t would be explained by the fact that the corresponding group of neurons in their states *actualize* a maximal interconnected set of causal relations between them, provided the parameters of the network at time t.

2. *Space as a collection of locations.* — I do not deny that this schema can serve as an epistemological model for what is present in an experience at a time t with properties of a neural network at this same time. However, I doubt that it accounts in its current state for what space *feels like*. This way of thinking about space in terms of delineatable areas in it resembles - whatever subtleties are introduced - the mathematical definition of a *topological space* which, rather than characterizing '*space*', characterizes a particular relation between a subject and space, that is the localization of '*objects*' in space.

[2] **S.Gangloff**, *A formal window on phenomenal objectness.*

[3] **A.Haun, G.Tononi**, *Why does space feel the way it does? towards a principled account of spatial experience*, Entropy 2019, 21(12), 1160

As a matter of fact, any collection of objects can be attributed a *topology* called *discrete topology*. Anything can be thought as spatial in this way, and we fall back on Kant's idea that space is a pure intuition - roughly speaking, anything that can be experienced is experienced in space.

3. *In contrast with the natural relation to space* — On the other hand, while abstractly any experience is spatial, it is possible to perceive and conceive space without holding in mind any formal representation of it. This observation provides a way to distinguish formal representations of space from the way space *feels*, which in principle, in the natural relation to space, should explain why formal representations of space are what they are - why for instance do we represent the space we live in as a three-dimensional Euclidian space ? For these representations are not simply random, it is reasonable to expect that they are the result of a construction based on a non-formal experiencing. Considering this construction process introspectively, we could be able to point at *what*, in the non-formal experiencing of space, determined the aspects that the formal representations of it have taken. Of course it is impossible to witness this process in oneself - precisely because a formal representation has already been constructed. However, it is possible: **(i)** to introspect on the process by which we *verify* that a representation of space actually represents it well, making more visible what in the natural relation to space makes one think that the representation actually and faithfully represents; **(ii)** to use thought experiments, in particular imagining other possible worlds - as sets of possible experiences -, introspect on how we would represent space formally in these worlds.

Such thought experiments would provide some reasonable hypotheses on how representations of space were actually constructed for the world we live in. Furthermore, I expect that this investigation shall provide means to think about the world thought formally - in particular the material world out-there - and the pre-formal world.

4. *Forgotten construction* — What characterizes A.Haun and G.Tononi's characterization of *what space feels like* as a collection of areas in the perception field is to rest in the post-formal world in which a particular relation to the ambient world has been constructed, taking '*objectified*' space - as it is characterized by a collection of mental objects - as a datum of all possible relation of a subject to its world. This idea resembles Kant's one, but differs fundamentally from it for the reason that it conflates space as such with its model. The theoretical attitude that A.Haun and G.Tononi adopt, searching for a datum of the subject's relation to the world which can be formulated formally, and subsequently finding it without thinking of it as a construction, can not but reformulate the result of a historical construction - the one of an analytic relation of the subject to the world. For instance what seems to be '*found*' when introspecting the vision of a uniformly white screen may well be the result of a *habit* of a certain relation with other, more meaningful, experiences, whose form has been cultivated and then forgotten as a construction.

For what I would like to do here, it is needed to be careful about what is

the result of a construction and what can be considered as a datum[4]. These attributes may only be relative: any thing designated can be a datum relatively to another one which is constructed relatively to the former - as the construction of the later relies on the presence on the former.

As G.Tononi usually presents them, the '*spots*' designate parts of the *scope* of visual or motor experience - which is all that is present at the present time in the subject's experience. They are constructed out of the presence of certain objects in the experience, and are left '*accessible*' when the objects leave the experience. More importantly, the scope itself is a datum relatively to the objects and therefore to the model of space - in the following, I will also use as datum the *movement*, understood not in its classical sense of displacement 'in' the space but rather as an '*action*' on the content of experience.

Only the query of the relation between the data and the constructed may reveal the *construction* by which the constructed is so out of the data.

5. *Relation between space and causation* — Another datum to consider is *causation* - which is a datum in the most abstract sense that there exist mental events which are causally related. I have borrowed from *Integrated information theory* the idea that the conceptualization of Experience in general relies on its causal structure; however I believe that the particular relation between causation and conceptualization that this theory points to - in particular in the case of space - is not the right one. In its technical aspect, the work of A.Haun and G.Tononi has consisted in relating the '*spots*' accessible mentally in the vision field to some subsets of neurons in a neuronal structure in some state, which are characterized by having - in themselves, not as collections of neurons - a non trivial cause and a non trivial effect. It is possible to be satisfied with such a formal correspondence if is accepted that it is meant to become more and more precise as the correspondence is progressively extended in order to include relations between other aspects of the subject's experience and other neuronal structures in a tighter and tighter way. However - as the reality is one and theories about it are many - this is unlikely if the theory does not echo the intuition.

When I try to make sense intuitively of the idea that something is present in my experience as much as it causes and is caused, then I am thinking that '*spots*' have a causal impact when there is a predator present in my vision field. In order to survive and decide *where* to run, I need to have '*access*' to the area of space where the predator is located. In this intuition, however, the sense of causation is different from the one of A.Haun and G.Tononi: first because they consider causation *inside* a neural network isolated from the remainder of the brain; second because they consider causation realized by actual events, rather than potential ones.

I believe that this case reveals another reflex in the mathematization of the

[4]Let us notice that the concept of datum essentially phenomenological, as it consists in the possibility to ignore the mode of presence - the way it appears for the subject - of the object considered as datum. As data 'science' grow, it is important to think more deeply about this (otherwise we would take the risk of considering as data what should not be and conversely).

world, which is that whenever there is anything which begins to be considered as having a (potential) mathematical characterization, is considered in order to formulate it only the closest *visible* construction which can immediately used for this purpose. Such absence of care for *unseen* possibilities may be easily explained by the rush into trading the outcomes of reflection, or simply sharing with the purpose of accelerating production - regardless of what precisely is produced - in a form of *intellectual capitalism*.

Instead, I think it matters to keep searching for a relation between space and causation in the intuition, considering this relation as a mathematical apparatus to come, in the long run, out of this dwelling in the intuition.

——— A screen and remote control thought experiment ———

In order to see *how* the constructed - a model of space which is faithful to the subject's experience - is so out of the data, it is useful to consider a thought experiment in which experience is reduced to the data themselves and then consider what properties of these data, *in* the thought experiment, may lead naturally to the construction of the constructed.[5][6]

1. *Formulation* — Here I will consider beforehand as datum the scope of experience and the capacity that the subject has to change its experience by motor *commands*: for instance $\mathcal{I}$ can choose at any time to move forward or backward, with effect on my visual experience in particular - objects get larger or smaller. The setting is as follows: the experiencing $\mathcal{I}$ am having is reduced to a screen on which appear some pictures in a set of possible ones[7] on which $\mathcal{I}$ can act using a remote control; this control consists in a set of buttons, each of which corresponds to a particular action; considering that the time is discrete, at each time $\mathcal{I}$ can choose to press a button or not. Variations on the set of possible actions and on the set of possible pictures lead to as many different thought experiments[8].

2. *Virtual reality* — Let us consider two kinds of worlds as sets of experiences. The first one is the set of images I can see in the eye of a microscope

[5] I believe that one should see thought experiments in philosophy not as problems to be solved, but rather as a way to render evident that which in natural experiencing differs from the thought experiment beyond its formulation.

[6] The the judgment that $\mathcal{I}$ am 'in' space marks the difference between M.Heidegger's concept of *In-der-Welt-sein* (Being in the world) and the later french translation *Être-au-monde* (Being to the world). The later is more fundamental in the sense that the way it designates the human mode of being is reduced to constituting moments that it can't be imaged not having, and corresponds to the setting of the thought experiment presented in the present paper. The former is more meaningful, for it points at an aspect of the relation to the world that is to be understood.

[7] These pictures can be continuous or discrete (consisting of a collection of colored pixels). For the development of mathematical concepts meant to describe with parsimony the conceptualization of experience, discrete experiences are more useful. For a purely phenomenological purpose, like the one which occupies me here, continuous experiences are easier to consider.

[8] One could introduce some variations on what the words '*reduced to*' actually mean. For instance I can imagine that the screen is embedded in the real world, while the remainder of the experience is considered to be '*simple*' - for instance a room whose walls and ground are uniformly grey.

when feeding it cells extracted from a living being, with the set of actions which consist in moving the microscope slide. The second one is the set of pictures I see when playing some virtual reality video game, with actions resembling the ones of the real world. These two examples differ by that in the second one, I feel like I am *in* the virtual world - although I ultimately know that I am not really in it, for it is only virtual[9]. What could explain this difference ?

——— On the constitution of the concept of space ———

1. *Space as possibility of movement* — To begin with, let us consider a simple set of possible pictures in which appear patterns that we conceive as '*spaces between objects*', for instance the one of *spaced dimers*[10]. Let us also consider a simple set of possible actions, which consist in disturbing one symbol and then finding the shortest way to come back in the set of possible pictures. Such action results in the displacement of a certain number of dimers. As a matter of fact, the reason why we tend to conceive the uniform patterns separating dimers as '*space*' may well be the fact that the presence of such pattern around a dimer allows to displace this dimer in multiple possible ways. If we liked to, we could formulate this in terms of causal relations - for instance, that the presence of such pattern, provided the presence of a dimer, realizes the maximum of indeterminacy for the possible results of an action in the set of possible ones. In short, space is what '*allows movement*'.

Let us attempt a parallel with the real world. Abstracting from particularities, one can see the world as composed of objects - such as a tree for instance - and spaces between them. While the tree is opposed to my movement - for I can't cross it - the space between two trees is not. In this context, however, the space between objects can hardly be interpreted as particular (type of) pattern in the sense found in the world of spaced dimers. As a matter of fact, in order to designate '*a space*' in the real world, I need to have already a notion of *depth*, or distance from myself of certain objects present in my vision field. We could then see this depth as part of the picture that I see, as an eidetic layer superimposed to the hyletic one; then '*a space*' is a pattern in this eidetic layer. More precisely, it can be designated using a pattern in the eidetic layer, which corresponds to an area of the vision field where depth is high enough. The designated space is a set of positions whose conception relies on the depth pattern and this conception relies on a model of the ambient '*space*'.

Before going further, let us notice that the idea of 'possibility of movement' may well be considered as an 'explanation' for the concept of space that we hold by construction, as it is tied more closely to the considered data - actions on experience and causation.

2. *Relating depth to objects' distance to reachability scale* — The eidetic pattern of depth relates to space in this sense: wherever there is depth, actions are effective - effect manifested as the change in the scale of objects present in the

[9] Let us notice that this sense of the world being virtual would disappear if $\mathcal{I}$ was born in it.

[10] Its description can be found in the text *A formal window on phenomenal objectness.*

experience.[11] How is the pattern of depth constructed ? There is (phenomenological) evidence that depth is related to the the scale[12] of objects currently present in the visual experience: *(i)* First, an object is 'close' when it is reachable, meaning that $\mathcal{I}$ can touch it without getting any 'closer', meaning that the scale of the object is not affected by this action. There is a relation between a certain scale - or rather, a range of scales, depending on the class of objects considered - and reachability, that the learning subject integrates with time. Then depth is the conceptualization of 'how far' $\mathcal{I}$ am from reachability range of the object, which is translated into the distance between the scale of the object as it appears in the experience and its reachability scale. *(ii)* Second, experiences without (non-formal) objects prove that the depth pattern depends non trivially on the presence of objects in the visual field. For instance, when I lie down and look at a plain blue sky, I am unable to determine any distance between me and what I see from this experience only. *(iii)* When $\mathcal{I}$ use a map in order to head to a 'position' in space from the one $\mathcal{I}$ am currently in, after $\mathcal{I}$ found on the map both of these positions, $\mathcal{I}$ search for a continuous path from one position to the other. This path designate another 'path' in the experience I have, which I have to follow in order to reach the second position. In order to do this, $\mathcal{I}$ usually - and unconsciously - cut the path on the map into small paths that are characterized by the fact that it is possible, when in the position corresponding to the initial position of this path, to determine from the experience in this position *how* to arrive at the ending position. Often times this determination relies on the presence of a certain object in the experience, and the small path is characterized as the straight line from the current position and the reachability range of this object, and following this straight line consists in acting on the visual experience in such a way that the scale of the object keeps increasing. When doing so, depth provides the information of the 'length' of the straight line - which, more fundamentally, is the ratio between speed and effort taken to follow it - separating the current position and the reachability range of the aimed object.

3. *Aspects of the construction of depth as an eidetic pattern* — The relation between depth and objects[13] is revealed by particular experiences in which the

[11] Of course when pushing an object which resists to this action, for instance, there is formally an effect, which is the sensation triggered by the motor interaction with the object. It is not taken into account in the term 'effect' that I use here; this term includes only effect on objects which are initiated by an action on the objects but independent on it once initiated.

[12] In the same way as the idea of 'possibility of movement' is more fundamental than the concept of space, the scale of objects is more fundamental than the depth pattern.

[13] Notice that this construction relies on a sense of which patterns in the experience count as 'object' and which do not. A precise characterization is the aim of the method developed in *A formal window on phenomenal objectness*; here I will not consider this problem and rather focus on the relation between objects and the construction of the concept of space, and rely on common sense in order to determine which patterns should count as objects. Let me only notice that it is possible to conceive objects as formed out of causality considerations, and that knowledge of causal relations implies the movement in space. However this movement is part of the natural relation to the world, and does not necessitate to hold any concept of space.

conception of depth depends abruptly on the context. For instance when $\mathcal{I}$ am looking at a picture of a tree, even though the scale of this 'object' is far from reachable scale, it does not look far away precisely because $\mathcal{I}$ see it on a piece of paper. First $\mathcal{I}$ infer the nature of what $\mathcal{I}$ see from the context - the piece of paper - and then attribute a depth to this area of the visual field which is based on the reachability of the piece of paper - and not the 'tree'. One time I was looking out the window of an airplane, I saw some large 'gray bubbles' out there in the sky and was surprised to see these untypical objects, provided the context. It happened that after moving the head a little bit, this interpretation changed - here the context was formed by other accessible experiences - and I was then looking at smaller gray bubbles *on* the window, probably because they were moving *with* the window as I was moving the head. After that I found out that what I was looking at were simply water drops, by answering the natural question which came to my mind: what on a window can look like bubbles ? In this example, the depth of the bubble is ultimately inferred from the depth of another object - the window. What is even more interesting is that the ontological construction order of the '*water drops on the window*': pure objectness came first, then depth, and then only the *nature* of the object. Sometimes depth of an area of the visual field which does not contain any object is inferred from the depth associated with objects nearby, for instance a section of blue sky between two houses.

Of course these examples do not exhaust phenomena related to the relation between objects and depth, which will most definitely be worthy of exploration.

4. Equivalence of possible paths and causation — It is relatively straightforward from experience to see that there are multiple ways to head towards an object, simply because I can slightly deviate at all time from the straight line which separates my current position from the one of the object. As a matter of fact, with time the subject learns laws of experience - which have causal nature - out of which it can form systematically classes of paths which are equivalent, in the sense that they lead to the same position from the current one. One such law is that when investing the same amount of effort into heading towards an object and then away from it - experiencially, the scale of this object increases and then decreases - or the converse, then I fall back on the 'same' experience.[14] When $\mathcal{I}$ do this, my actions 'cancel' each other. This can also be interpreted as a causal relation between the current experience, together with the actions of *moving forward* and then *moving backward*, on the experience I will have then.[15] As well $\mathcal{I}$ can conceive from experience certain actions which leave invariant the scale of 'most' objects in the visual field, as well as ones which move all objects in the same direction - left or right. This is how $\mathcal{I}$ conceive what *turning around*

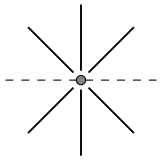
[14]There is probably a clear notion of what 'same' means here; for now let us only think about such laws over a very small period of time and neglect 'slight' changes.

[15]The interest of this remark is that it is in principle possible to imagine a world in which different laws apply on experience, such as for instance: when $\mathcal{I}$ turn around myself 'long enough', all colors are inverted. How would the concept of space change if the system of causal laws on experience was different ? In other words, how exactly does the concept of space depend on them ?

oneself means. Once $\mathcal{I}$ have this conception, then $\mathcal{I}$ can observe that the two actions of turning around myself on the right and turning around myself on the left cancel each other, but also that there is a certain amount of effort, the same for each of these actions, for which $\mathcal{I}$ fall back on the initial experience.[16]

With that we can formulate the equivalence between paths which consist in the straight line towards an object and all possible intertwining of this straight line with turning around oneself for instance.

5. *Being 'in' space* — Once $\mathcal{I}$ conceive what *turning around myself* means, I can conceive half of the amount of effort taken to do a complete turn, and learn another causal law that the experience that I have when doing a half turn and the experience I have currently exhaust together all I can perceive when turning around myself - any thing perceived can be obtained by extracting from these two experiences and assembling the extracted pieces together. Furthermore, moving backwards and then turning around is equivalent to turning around and then moving forward. With time, the subject has at all time in mind a concept of 'what is behind', or of what experiences completes the current one, together with a depth pattern. It seems to me that this is the point from which the judgment that $\mathcal{I}$ am in space appears, for $\mathcal{I}$ lie *in between* two depth patterns. More precisely, it is constructed out of the analogy between the experiential situation $\mathcal{I}$ am in and a geometrical structure - which by this analogy becomes a faithful *representation* of this situation - such as the following one.



In this simple picture, the circle on the center represents the position of the subject, the dashed line separates the current experience and the projected one *behind* and the other lines represented the projected depth on the objects present in the visual field. By analogy $\mathcal{I}$ am 'in' space as the central circle is in a circular area around it, that the lines draw.

6. *Return to the analysis of space* — It is by the same type of correspondence that the subject builds the judgment that the Euclidian concept of space is a faithful representation of the space it is 'in'. A segment in the plane has certain properties shared with the experiential straight path towards an object: for instance that one can follow this segment in two directions such that one movement cancels the other at any point[17]; any picture in the plane is invariant by a certain rotation (by 360 degrees); there are many paths from one place to

[16] In a similar way as $\mathcal{I}$ conceive the action of *turning around myself* $\mathcal{I}$ conceive *turning around an object*. It is possible that a mapping between the series of experiences I have in the two processes leads me to conceive the notion of 'point of view' from the position occupied by the object.

[17] Let us notice here that one way to see that experiential paths towards objects are more fundamentally tied to the experience than the model is that the natural relation with the world does not need the conception of points. As a matter of fact no object is ponctual, and

another which I can distort in a similar fashion as continuous curves in the plane; they can be followed at any desired (and variable) speed. Some ideas might be brought from the analogy itself to the experience, such as the possibility to go from one fixed point to any other by going in a fixed direction and then turning around with a *right angle*[18] and then follow again a straight line - in the plane, we can describe the relative position of any point to another fixed one by coordinates relative to two orthogonal infinite lines whose intersection is the fixed point. Similarly $\mathcal{I}$ identify an area of space by an exploration of a set of experiences defined by fixed object-boundaries as in the plane by a free movement inside and not crossing a closed curve boundary. In the experience there is 'always' another area of space beyond any area, as in the definition of Euclidian plane.

One may notice that the way the faithfulness of a the Euclidian model for space is 'verified' is similar to the one by which the faithfulness of a model for computation such as A.Turing's computing machines is 'verified', meaning by experiencing space in the reality and in the model as set of experiences, comparing and the identifying the conceptualizations of these experiences and concluding to their similarity. It is by generalizing the means by which these models are constituted that we could arrive at a formal understanding of other aspects of the relation between the subject and its world, such as *objectness*, or how the elements of computing are assembled in the subject and relating to experience.

——— **Furthermore** ———

The last section was only meant as a first exploration, and certainly does not exhaust all there is to say about the constitution of the concept of space.

1. *Other worlds* — One way to explore this which I am leaving open is to think of other worlds, as sets of possible experiences, in which the natural conceptualization of space would be changed. This is a rather difficult direction to take, because of its non-definiteness, but let me draw here some ideas in this direction. It is possible to 'break' the conceptualization of space as in the world out-there is to think about a world in which objects never change scale. In this case, all experience would feel 'flat' - in other words, $\mathcal{I}$ would conceptualize this world as only two-dimensional. In fact it is possible that in some of these worlds, space would be conceptualized in a completely different way, not limited to dimensionality[19]. Considering intermediate worlds could lead to a better understanding how space really *feels like* - not how it is analyzed - or felt like in the pre-conceptual world. Another possibility would be to 'break'

---

the analogy between points and objects is reducible to the function of ending the movement towards it along a segment or a curve, in a similar way as objects in the experience.

[18] In practice taking a right angle turn is not that simple, and are needed some identified orthogonal segments which are recognized as such because when rotating one around their intersection with constant speed, it takes a quarter of the time taken for this segment to come back to its initial position.

[19] First exploration, using a method similar to the one of *A formal window on phenomenal objectness*, that space could be characterized across worlds as patterns of 'vanishing' causation.

the conceptualization at the level of what I called causal laws on experience, such as the cancellation of 'moving forward' and 'moving backward' actions. I imagine that the world would not be conceptualized at all as a Euclidian anymore; but what exactly makes this change and how ?

2. *What gives unity to the concepts of space ?* — This is one question of interest to keep in mind in this exploration; in other words, what have in common the various possible ways to characterize space across worlds ?[20] As well, what makes unity of the elements constituting one concept of space: why are they thought together rather than separated ? What makes space differ from objects in general ?

In order to approach these questions, one way is to see how spatiality and objectness differ in the respective characterizations in causal terms. One difference, at first sight, is that causal relations which constitute the concept of space are universal, in the sense that they consist in relations between any possible experience and another one obtained by transformation of it, while objects are causal relations between parts of experiences which group these experiences together.

3. *How is the concept of space 'stored' in the brain ?* — In principle, the interest of a description for the construction of the concept of time is that it 'breaks down' the concept into elementary ones, such as causal relations and the hyletic layer of experience, which themselves are put more easily into a correspondence with sub-structures of the brain - for instance simple causal relations may well correspond to neurons, as well as algorithms, obtained by combining causal relations, correspond to neural structures. From such a description we would be able to point out what structure obtained out of these elementary sub-structures of the brain corresponds to the concept of space. Contrary to the 'spots' of G.Tononi and A.Haun, the construction of the concept is properly identifiable with it (for as a construction, it contains in principle as least as much 'information' as the concept that it constructs), and this makes the correspondence faithful.

From the short analysis above, I am led to think that what we usually refer to as 'space' is only the trace of what it is, a trace fitted to material usage, an 'incarnation' of a more complex actual relation with a world of spatial nature, which *appears* as a set of objects in this context because of the nature of the context - material usage requires objects. In the search of a correspondence between 'space' as such and the structure of the brain, we should not assume

[20] R.Carnap, in his thesis *Der Raum*, examined different ways theoricians analyze and define space, in particular secluding different *types* of spaces - namely formal, intuitive and physical space, arguing in particular for the possibility for these types to co-exist in a faithful representation of the world, leaving open philosophically the possibility that physical space could be better represented by other mathematical constructions than Euclidian space - in particular the ones of relativity theory. What I propose here differs from R.Carnap's philosophy in the sense that I would like to think of the concept of space as a 'function' of the world as set of experiences, reflecting its (causal) structure. Furthermore, how to explain that there is a natural concept of space at all for a fixed world, and why do we think of what it refers to as 'space' ?

that this concept may well be understood in the terms of material usage and therefore identify it with its trace. In the same vein, we should not search for a structure in the brain corresponding to the concept of 'space' which would be composed of elementary structures of the same nature as the ones corresponding to the elementary concepts that we identified first as composing it - in fact this could be seen in the the fact that 'space' and objects differ in their relation to the causal structure of the world[21].

4. Time — It is natural to wonder: why not beginning with 'time' instead of 'space' ? It is natural because we acquired the habit to assimilate them, to translate one into the other. However, while they have similar models, fitted for material usage (or theoretical one as for the development of relativity theory) - and in particular the translation one into the other - they differ from the point of view of the subject's analysis and understanding: for instance, it is more difficult to differenciate multiple concepts of time and to see that there is a more fundamental one relatively to experience. Furthermore, time is less fundamental than space in this sense, for its constitution as a concept requires the one of space: time measured by a clock depends on the space traveled by the hand; one could object that this 'time' is not 'pure time', as measured by a process - for instance the simple alternation of light and non-light - which does not travel any space, however the definition of this 'pure time' requires space, howbeit negating its involvement in the process[22].

There is an additional difficulty, that the 'form' of time seems to depend more on the subject's choice of relation to the world, and choice of beliefs. For instance, while it is reasonable to think that time is 'locally' linear, it is not clear whether the 'whole' time is time linear or circular. Let us consider a process which consists in the alternation of light and non-light. If this process was the whole world, would time be circular or linear ? It is one or the other if $\mathcal{I}$ want to: $\mathcal{I}$ can consider that any event of light is identical to all the other ones and choose to believe that time is circular, for there is no necessity to consider it otherwise; or $\mathcal{I}$ can choose to consider each of the light events as different, and choose believe that time is linear, for the information of the number of events of this kind could matter later[23].

[21] Contrary to the proponents of *Integrated information theory*, I think that we should not *a priori* search for a *uniform* way to characterize what exists for a subject, what I believe is proved by the example of 'space'.

[22] In this direction, I think that it would be of interest to answer more precisely the following question of "how to explain the judgment that time is different from space exactly ?" as a way to understand the relation of space and time, not as in relativity theory in which models of space and time relate geometrically, but rather how they relate in their constitution as concepts.

[23] A similar observation could be made on the relation between time and causation: we often choose to choose to analyse the world through causal relation which relate instants close to each other; event though it is not clear that there can not be long range causal relations without intermediate (would we believe that time is linear then ?), at least we can see that any chain of 'local' causal relations generate other causal relations obtained by composition of these local ones. These 'higher level' causal relations may actually matter in order to explain how we conceptualize the world.

Albeit these difficulties, it is in principle possible to consider the constitution of the concept of time ; in this direction, I believe that what is the most fundamental relatively to experience is, for each 'present', the set of events which are 'pseudo co-present' to it in the sense that they are the object of a continuous retention, from the time they happened to the present - with a similar characterization for the events to come.