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Kant's Epistemology and Neuroscience: The Biological Basis of the Synthethic and "A Priori" Character of Geometric Knowledge

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ABSTRACT:

This exposition intends to demonstrate that Geometric Knowledge is a kind of synthetic knowledge according to Kant's definition. We also intend to emphasize the presence of an *"a priori"* component in this knowledge, apart of its most evident empiric portion. We shall initially discuss Kant's concepts of *"a priori",* empiric, synthetic and analytical. In the sequence we expose our arguments in favor of the presence of a synthetic and *"a priori"* component in Geometric Knowledge. This discussion will be based in current knowledge of neuroanatomy and neurophysiology. This approach will provide us insights about the way geometric forms are integrated in our minds, form afferent sensitive pathways up to cerebral regions (mainly posterior parietal cortex) responsible for synthesis of these primary sensorial data in a consistent whole to be presented to our consciousness. Our objective is to relate some parts of this cognitive process with Kant's concepts about Geometry, corroborating, this way, his philosophic statements with neuroscience substrates.

1. INTRODUCTION

"*The possibilities of sensorial Inputs interpretations are based in our inborn dispositions, which derive from genetic instructions for the construction of the brain*"
John Eccles [1974]

"*There is no human experience, and no experience is possible, without subjective availability... it consists in an inborn psychic structure which is the factor that allows men to build and live this experience*"
Carl G. Jung [1928]

2. DEFINITIONS

Initially, we would like to define some concepts that will be used along this exposition, intending to standardize some terms, with the purpose to achieve a better level of comprehension, and to provide more consistency to the arguments presented. This conceptual definition is an important part of this article, since confusion between the terms here applied, can alter significantly the understanding of our ideas. (An example of this would be a confusion, of what we call "*Geometrical Knowledge*" with the concept of "*Geometry*" used when we speak, for example, about Euclidian or Non-Euclidian Geometry. - see definition of *Geometric Knowledge*)

2.1 SPATIAL PERCEPTION

Spatial Perception is the phenomenological representation in human mind of aspects related to position and spatial relations among objects of the real world. We are not discussing here Geometry as "*numenum*" (thing itself,) but as a geometric phenomenon, in other

words, the way it presents itself to our consciousness. This is a special kind of Geometry, particularly that whose definitions of the abstract terms are more similar to the way our mind pe frceives the geometric phenomenon.

2.2 SPATIAL IMAGINATION

We saw that one source of geometric relations is the experience (*Spatial Perception*). However, we can easily see that this is not the only way. When we imagine, we are also capable of thinking geometry and spatial relations, even if these elements do not have any component derived from experience. As said by Aristotle: “The Imagination (phantasía) is the reproduction of the sensation without the presence of the sensible object” [1].

Here someone raises the objection that, when we imagine, what we are doing is bringing the special aspects of previous experiences through our memory. We would like, using an example, to demonstrate that, even though the basis of imagination can be a previous experience stored in memory, this fact is not necessarily true for all the imaginative facts. Let’s take as an example the case of visual imagination. Of course we can, using memory, imagine something that we suppose to be similar to a perception of a scene that occurred some time ago. I say similar, because the essence of imagination is the lack of exactness and clarity, distinguishing from perception itself, which is concrete, clear and exact. However, let’s imagine someone who is blind since birth. Certainly, this person has not had any previous visual experience. However, this person can certainly form images with spatial content in his mind. To prove this fact, we can ask this blind person to draw in a paper what is “in his thought”, and certainly, we would see a figure with spatial characteristics similar to those experienced by anyone else. The fact that this person never had any spatial character experiences doesn’t suppress his natural capacity to think spatial relations despite experience, and this ability can be used to form figures through the

process we call *Spatial Imagination*. We could say that this natural capacity is “a priori” or before any experience. This a priori component is the only that operates in spatial imagination, and is combined in spatial perception with sensory data provenient from experience.

Notice that both *Spatial Perception* and *Spatial Imagination* are phenomenon of consciousness; in other words, are phenomenon which occur in a determined instant to a determined individual in particular. They are both personal mental processes whose occurrence can be determined temporarily.

2.3 SPATIAL COGNITION

The *Spatial Cognition* corresponds the capacity an individual has to perceive spatial relations between objects, as well as notions of depth, solidity and distance. This capacity is given specifically by the posterior parietal region of the brain’s right hemisphere which, when injured, result in various types of *Spatial Cognition* deficits. (*see Appendix for more information about the Posterior Parietal Cortex and its relation to Spatial Cognition*)

Spatial Cognition gives us the capacity to integrate the sensorial stimulus in an adequate way to form spatial perception, as well as to imagine spatially despite experience. Any disturbs in *Spatial Cognition* will result in deficits and alterations in *Spatial Perception*, as well as in *Spatial Imagination* capacity. Here we should emphasize that, in opposition to *Spatial Perception* and *Spatial Imagination, Spatial Cognition* is not a consciousness phenomena. It is not an event that occurs in our minds, but the capacity that underlies and makes possible all experiences. It is also a priori, because this capacity must exist before the occurrence of any experiences.

2.4 GEOMETRIC KNOWLEDGE

We understand as *Geometric Knowledge* that knowledge which

can be obtained through information present in *Spatial Perception* or *Spatial Imagination*, or where it can be deduced from any of them. One of the origins of *Geometric Knowledge* can be *Spatial Perception*, being composed of the manipulation of sensorial information with origin from sensorial canals (sight, hearing, touch). However, *Geometric Knowledge* can also derive form *Spatial Imagination*, where no empiric sensorial data is found.

Geometric Knowledge is, therefore, the objective information which can be obtained from both *Spatial Perception* and *Spatial Imagination*. However, while these are consciousness' phenomenon of a determined individual, *Geometric Knowledge* is the relation between concepts and laws (axioms, theorems, rules). This knowledge is, therefore, information that, although obtained through psychic phenomenon (perception and imagination) is not, in itself, a phenomenon of consciousness, and do not have, therefore, the temporal and personal character imposed by it. For a comparison between the used terms see table 1.

	COMPONENTS		**OBJECT CLASS**
	A priori	Empiric	
Spatial Perception	x	x	*consciousness phenomen*
Spatial Imagination	x	NO	*consciousness phenomen*
Spatial Cognition	x	NO	*mind ability*
Geometric Knowledge	x	x or NO	*group of axioms and theorems*

Table 1: Table demonstrating characteristic of theoretical terms

3. EMPIRIC KNOWLEDGE X "A PRIORI" KNOWLEDGE

Empiric knowledge is that based in experience. It is “a posteriori” in opposition to the one who exists before any experience. For empiric knowledge, only sensorial observations can offer the kind of argument that a person needs to be in conditions to say that a certain judgment is true.

For Kant, strict universality and necessity are safe signs, each one infallible, that knowledge is “a priori”, not empiric. Sciences such as Physics, Biology and History – especially worried with matters related to empiric knowledge – must be settled in observations if we want to see conclusions established. In opposition, subjects such as Logic, try to obtain “a priori” knowledge of the rules that govern the validity of arguments, not needing, therefore, observations to achieve its conclusions. In this way, the question we face is: what about the *Geometric Knowledge*? In this particular matter is it similar to Physics, empiric or Logic, “a priori”?

4. ANALYTICAL KNOWLEDGE X SYNTHETIC KNOWLEDGE

According to Kant, to know something or to believe in anything is to elaborate a judgment. Kant described a mental act to formulate a judgment as an act of connection of concepts, united in consciousness [2]. According to this view, someone who knows that all dead people are non-living joined, in his consciousness, the concept of “dead” and the concept of “non-living’ (this person used what logic names universal and affirmative connector). In another example, someone who knows that dogs don’t fly unite, in his consciousness, the concept of “dog” and the concept of “fly” (using the universal and negative connector).

Kant imagined that a distinction should be established between two kinds of basic judgments. In one side, we have those where the mind synthesizes or joins concepts in a way that doesn’t resemble any previous connection that both might have: these are called synthetic judgments [3]. The judgment, for example, that “no dog flies”, is a kind of synthetic judgment, because there is nothing, in the concept of “dog”

that intrinsically excludes the flying.

On the other hand, there are judgments where the mind analysis a concept, and by a simple application of logical rules, it develops a conclusion. These are called analytical judgments. The judgment, where “all dead are non-living”, is an example of analytical judgment, since the concept of “non-living” is an intrinsic part of the concept of “dead”.

According to Kant’s ideas, we can affirm that the distinction is: one judgment is analytical if, and only if, nothing more than reflection about concepts contained in premises is necessary to reach the consequences [4]. A judgment is synthetic if, and only if, the reflection about the concepts contained in premises is still not enough to determine the truth about the judgment, or to reach the consequences.

According to Kant, the paradigmatic examples of analytical truths would be the logical statements, truly only because of its logical form, despite its content. Kant sustained that all statements whose truth depends only on its logical form is analytical. One statement would be synthetic only if is not analytical [5].

The matter of how to verify the truth of the synthetic concepts was brought up, once that mere intrinsic coincidence isn’t enough to justify them, like in the case of the analytical judgments. To synthetic judgments, it is necessary to have something more, in Kant’s terms, a tertium quid (a third thing) that would allow the joining of premises and consequences making the judgment true. In relation to the synthetic judgments of empiric character, this “third element” capable of justify, would be the sensorial experience. I have already seen several elements that fit in the concept of dog, and none of them flew. Through induction, and based on a relatively large number of empiric observations, I get to the synthetic judgment that “no dog flies”. This judgment can, of course, lose its validity if, for example, one day I find a dog that flies; this fact would annul the corroboration given by the third element experience to the synthetic judgment.

Following these lines of reasoning, we could easily perceive an easy rule: that analytic judgments are a priori – and do not depend on experience, and synthetic ones are empiric, dependent on experience.

What is there to say, however, about synthetic judgments “a priori”? Suppose we have an “a priori” knowledge (that is, before any sensorial experience) and synthetic (that is, not justifiable by the intrinsic connection of used concepts – in other words, a judgment where consequences are not justifiable by the logical form of premises). These are what Kant called “Transcendental Conditions of Objectivity”. These are “a priori” but synthetic knowledge. They are a priori because they are before any experience, but are synthetic because they cannot be derived from simple logic deductions. They are contained in every experience, but there are conditions previously established, and not part of them. These conditions are in Physical Sciences categories, in a total number of nine, and in Mathematics two: space and time.

An easy way to understand what these are a priori and synthetic knowledge is looking at the process of representing the world as knowledge. In this schema, we have first the subject of knowledge in face of the real world or “*thing itself (Ding a sich)*” or like Kant named: “*numenum*”. Between the world and the subject, there are the Transcendental Conditions of Objectivity, through the “glasses” where the subject see the reality. In the heuristic process of knowing, the world is perceived and represented in human mind. At the last point of this process, the knowledge is generated. This knowledge is, in fact, the properties, rules and relations between concepts and representations.

5. DEMONSTRATIONS

5.1 GEOMETRIC KNOWLEDGE IS SYNTHETIC

To Kant, it seemed evident that fundamental geometric laws were not simple verbal truths and that is not possible to make them equivalent to vacuum logic truths. Kant sustained that the fundamental laws of

Geometric Knowledge and definitions of primitive terms had an essentially synthetic character [6].

Consider the statement of the geometry: that the sum of the angles of a triangle is equal to two right angles. This statement is synthetic, according to the second version of the differences, since it is not true only because of its logical form. Nothing in logics says that the sum of the angles of a triangle needs to be 180º. This is truth, but only because we are considering as basis the Euclidian Geometry. There is nothing in logic that makes us consider this Geometry as the only true. It's only because how we will see ahead, the Euclidian Geometry is "a priori", or better saying, that one who fits our perception better, where we think necessary this equality. In other words, it is not logic who demands the sum of the angles of a triangle to be 180º, but the Euclidian Geometry. When we study the Riemann's Geometry, per example, the sum of the angles of the triangle is always more than 180º. We believe this judgment is synthetic once it is not logically necessary.

S. Baker presents the following definition in order to help to characterize the analytical character of some statement [7]:

"A statement could be qualified as an analytical statement if nothing more than the comprehension of the affirmation is necessary to know that it is true. To notice that it happens this way, consider the imaginary case of someone who, examining a statement, doubted of its authenticity. How to describe the intellectual situation of this person? If a person doubted of such a statement, the doubt should itself, be enough to reveal that she/he didn't comprehend the statement". In opposition to analytical statements, in synthetic judgments, someone is allowed to doubt about the statement, even having comprehended it.

When someone says that "no dog flies", it is perfectly possible to, at the same time, comprehend and doubt about it, by raising or imagining the possibility of an unknown dog that could perhaps fly. The person had fully comprehended the statement, and is still capable of raising objections.

According to this definition, would *Geometric Knowledge* be analytical or synthetic? Is geometry valid only because its terms or is it possible to have doubts about its statements? It is clear for everyone who studied analytical geometry that in order to judge a statement like: there is no unique plane that contains two perpendicular straight lines, it is necessary to "think" about it, or to represent the situation in our imagination. The simple analytical reflection about lines and planes is not sufficient to make our statement true or false. It is necessary to appeal to our spatial cognition, to an inner reality of the space represented in our minds, which, as seen it before, can be a representation of space out of us (in the case of spatial perception), or simple mental constructions (in the case of spatial imagination).

We could, therefore, say that geometric knowledge is synthetic once:

1) Its statements are not valid or invalid by themselves, or by its logical form.
2) There must be an inner experience in our minds in order to embase the validity or falsity of statements.

5.2 GEOMETRIC KNOWLEDGE HAS AN "A PRIORI" COMPONENT

The concept of "a priori", as Piaget explains, includes three aspects: the idea of necessity, the idea of previous logical condition and the idea of previous genetic condition. It is the reference to this last aspect to the concept of "a priori" that we refer to when we say that *Geometric Knowledge* is "a priori". We mean that *Geometric Knowledge* depends on *Spatial Cognition,* biologically and genetically determined.

About the possibility of geometry be considered an *"a priori"* knowledge, S. Baker affirms [8]:

"The axioms and theorems of Geometry do not need to be empiric statements; they can be announced "a priori". Geometries postulates can only come to be true or false when they receive a specific interpretation."

The *Geometric Knowledge* a priori component would be a peculiarity inserted in the sensorial information of the human brain, in a way to form the *Geometric Perception*. It is a tendency of the human mind, determined by a certain pattern of neuronal circuits, integrating of spatial sensorial information, received from the outer world, in such a singular way. It corresponds in Kant philosophy to a Transcendental Condition of Objectivity (the glasses through reality is seen. This is the way *Geometric Perception* is created. It is similar in all human beings and it is determined by pattern of neuronal circuitry of human brain. That is why it is "a priori", because it is independent and before any form of sensorial experience.

According to what Piaget affirms [9]:

"*Perception is assimilated, since the beginning by cognitive mechanisms in superior level to it, which make it inclined to certain particular interpretations. Perception never offers by itself direct information as if it were a copy of the object, as logical positivists defend. Perception itself contains perceptive schemas as well as an unconscious pre-inference."*

Perception would be, therefore, a process that has a subject, fits the object, classify it, and enriches while perceives it. This goes against the pure empiric philosophy, who affirmed that the object is already pre-established in all of its characteristics, done, finished, and we do nothing more than have access to these preexistent qualities. This conception, however, despises the subject of knowledge and presents itself as an inadequate simplified epistemological process.

Our pure sensations cannot give us the notion of space. This notion is built by the mind during integration of sensations, and this integrative operator and transformer is the neuronal circuitry of the posterior parietal lobe, the neuroanatomical area responsible for *Spatial Cognition*. The sensations itself do not have any spatial characteristic. Without the action human brain, the search for spatial perceptions and the measuring of different positions would be like trying to find a difference between a smelling and a visual sensation [10]. Our

sensations differ one form from another qualifiedly, and there cannot be, a same measure among them. Such classification and ordination of all inputs in a “Spatial way” is made by an “a priori” element, innate, as Kant would say, that preexists in us.

The *“a priori”* component of *Geometric Knowledge* becomes more explicit when we consider its origin from *Spatial Imagination*. As we previously saw, it is possible for a person to think spatially without the empiric information provided by an external object in that moment (perception), or in the past (memory). In spatial imagination’s case, the origin knowledge is essentially “a priori”; in other words, it resides in the innate capacity to think spatially.

6. CONCLUSION

We could therefore conclude that:

- *Spatial Cognition* is the innate capacity that permits the individuals to “think spatially” and it provides the “a priori” component to Geometric Knowledge. The posterior parietal cortex is the neuroanatomical structure responsible for spatial cognition. It could represent the Transcendental Condition of Objectivity of Space in Kant Philosophy.
- *Spatial Perception* is said to have two components: one “a priori”, derived from *Spatial Cognition* and one empiric, derived from sensorial information, while *Spatial Imagination*, has only the “a priori” component. This way, *Geometric Knowledge*, when originating from *Spatial Perception*, will also have two components: one empiric and one “a priori, while *Geometric Knowledge*, when originating from *Spatial Imagination*, would have only the “a priori” component.
- *Geometric Knowledge* is synthetic because its characteristics do not depend on logical deductive rules but on biological structure which mediates it.

7. APPENDIX - THE POSTERIOR PARIETAL CORTEX

The posterior parietal cortex is a complex heteromodal association area related to geometrical and spatial process, which receives input from many other brain activities and integrates them in order to provide a whole representation of spatial aspects of the forms of outer world. [10] Inputs from visual areas, tactile area, proprioceptive and auditive area are all integrated, providing the subject the capacity of constructing an internal map of the world [11]. (figure 1) It can combine this internal map with decision and wishes generated in other cognitive areas of frontal lobe and send these spatial information to motor area for example, which will be responsible to structure plans and limb movements in order to perform appropriate movements in the outer space [12]. The posterior parietal cortex is not a dedicated center containing a spatial map but a critical gateway to access and integrate information related to the attention-related representation and exploration of the external space [13].

When this area is injured, modality specific information channels (for example, visual and auditory) related to extrapersonal space can remain intact, but they can't be combined to create the interactive and coherent representation necessary to the adaptive development of spatial attention. It is called "*parietal lobe* syndrome" [14]. Patients with this kind of disturbance fail in "mental rotation" tests, and are not capable to identify objects seen in an uncommon perspective; they find paths and ways, and navigate their own body in relation to external solid objects like chairs and beds [15,16].

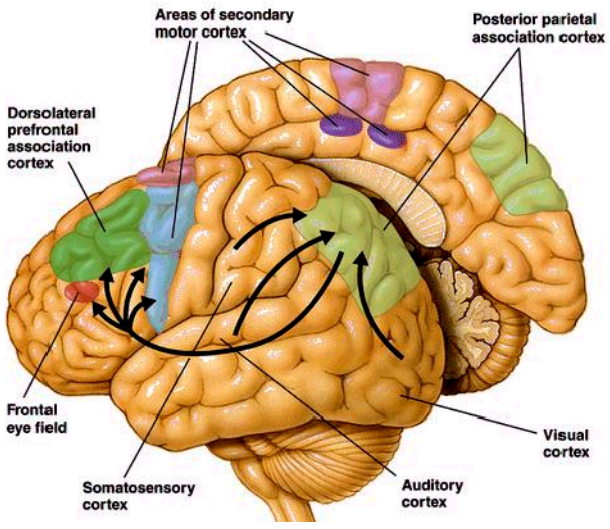

Figure 1: Schema of cortical brain areas related to spatial cognition. Note that posterior parietal cortex is multimodal association areas which receives input from several other areas.

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