SCIENCE RATIONALITY AND INFERENCE: AN INSIGHT FROM COGNITIVE PSYCHOLOGY

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Resumen

El propósito de esta exposición es analizar los *procesos inferenciales* conductores de la ciencia que llevan a ésta a constituirse en un sistema racional asertivo más allá de sus contrapartes irracionales. La racionalidad es un aspecto central y crítico para la ciencia, sin embargo, puede reflejar una necesidad psicológica y cognitiva de la organización del pensamiento destinada a establecer un balance entre categorías estables del entendimiento y el flujo inestable y dinámico de inferencias dirigidas a representar los diversos problemas científicos. Se supone la existencia de procesos dinámicos entre inferencias implícitas y explícitas, en la resolución racional e irracional de desequilibrios entre las representaciones científicas y las diferentes heurísticas de los científicos. Se analizan algunas categorías de razonamiento modal que se consideran como substratos inferenciales utilizados para justificar y moldear el conocimiento y también se ven las inferencias implícitas y explícitas como procesos sistémicos y de complejidad destinados a atender las necesidades racionales de orden, coherencia, cierre lógico, reversibilidad, etc.

Palabras clave: Procesos inferenciales - racionalidad de la ciencia - ciencia y cognición - epistemología y cognición.

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Abstract

The purpose is to analyze inferential processes leading science to constitute as an assertive rational system from its irrational counterparts. Rationality is critical for science, however, it reflects a psychological need of thought's organization to achieve balances between conflicting stable categories of understanding and changing flows of inferences attending scientific problems. Dynamics between implicit, and explicit inferences is assumed in the way to solve rational, and irrational unbalances between scientific representations, and heuristics. Modality categories are analyzed as inferential substrates to knowledge justification, implicit, and explicit inferences as systemic and complexity processes attending rational needs for order, coherence, logical closure, reversibility, etc.

Key words: Sciences inferential processes - sciences rationality - sciences and cognition - espitemology and cognition - sciences inferential systems.

Rationality is a special attribute aimed at by science as a logical and critical requirement to be accomplished every time. However, from another view, rationality configurates a psychological need for solving cognitive conflicts and achieving an internal balance against ambiguity, vagueness or contradictions between antagonistic statements, and representations. Rationality is usually related to needs of satisfying, and filling credibility gaps, as well as it is involved in people's persuasion and self-convintions to recognize what is true or false, correct or erroneous, and to prove truth beyond doubt. Whenever people claims for a satisfactory response, it uses to be a rational (or perhaps a reasonable) response. So rationality constitutes a normative control evaluation requirement as well as a cognitive need for balancing representations, and self-convincing arguments.

An inquisitive approach combining both normative, and cognitive needs would analyze the inferential processes that lead science to constitute itself as an assertive rational system as from its irrational counterparts.

Some authors have been striving for including the cognitive approach into the epistemological analysis of science. One of them is Goldman. Goldman (1986) whose aim is restructuring the field of epistemology beyond philosophy, dividing epistemology into two parts: *individual epistemology,* and *social epistemology.* Of both, at least individual epistemology (he says) needs help from the cognitive science. Cognitive science tries to delineate the architecture of the human mind -brain- an understanding of this architecture, Goldman says, is essential for primary epistemology. Social epistemology needs help from social sciences, and humanities, which jointly provide models, facts, and insights of social systems of science, learning, and culture. Epistemology, whatever it be, deals with knowledge, which is the property of individual minds. So, epistemology must be interested in the knowing of the mind.

On our part, we consider that all knowledge, including scientific knowledge, has a cognitive-psychological substrate beneath its epistemic substrate. However, as Goldman notes, strong countercurrents in the history of epistemology run against the above interdisciplinary approach. Goldman points up that one crucial component of epistemology is its evaluative, and normative mission, however he recognizes that:

> "on a purely descriptive conception it is not surprising that epistemology should be indebted to psychology - and should even reduce to it" (p. 2).

Following a similar tenet, a modern logician like Quine, imbued in his naturalistic conception of logic, asserts that the epistemologist should study how the human subject responds to certain input; also how, in response to various stimulus patterns, the subject delivers a description of the external world and its history. So (he points) in studying the relation between the *meager input* and the *torrential output*, epistemology

> "simply falls into place as a chapter of psychology and hence of natural science" (1969, p. 82).

Similarly, also Campbell (1974) advances a conception of the field which he calls *evolutionary epistemology*. On this conception epistemology takes cognizance of

> "man's status as a product of biological and social evolution" (p. 82).

Campbell explicitly characterizes his conception as descriptive of man as knower.

Goldman also argues this way:

> "If epistemology is a branch of psychology, or evolutionary theory, the field's empirical status needs no clarification. But ... epistemologists have traditionally been interested in whether beliefs about the world are justified or warranted; whether we are rationally entitled to these beliefs -seek to discover or invent proper methods of inquiry and investigation, often dismissing established procedures as irrational. Clearly, 'justified', 'warranted', and 'rational' are evaluative terms; and the advocacy of particular methods is a normative activity. So traditional epistemology has a strong evaluative-normative strain" (p. 3).

Against this traditional view, Goldman argues that logic, probability theory, and linguistic analysis cannot by themselves delineate principles of rationality or justified belief, memory, representational constraints, internal codes, and so on. However Goldman also holds that:

> "epistemology is an evaluative enterprise, and the prime object of its evaluation are arguments, or forms of inference" (p. 4).

In such case, epistemology is not primarily interested in inferences construed as argument forms, rather it is interested in inferences as processes of belief formation or belief revision, as sequences of psychological states. Furthermore, additional psychological processes are of equal epistemic significance: such as processes of perception, memory, problem solving, and the like.

Why is epistemology interested in these processes? asks Goldman. One reason is its interest in epistemic justification, but the notion of justification is directed, principally, at beliefs, and beliefs (Goldman contends) derive from evaluations of belief-forming processes. Which of these processes are suitable cannot be certified by logic alone. Ultimately, the justification a status aimed at by science depends (at least in part) on the properties of our basic cognitive equipment. Hence, epistemology needs to examine this equipment to see whether it satisfies or not some standards of justifiedness. So, the architecture of cognition constitutes the focus of what Goldman calls *primary (individual) epistemology*.

But, what is really rationality? Where does its concept come from? Why is basically seen as logical and epistemological, rather than cognitive and psychological?

Historically, ancient Greeks postulated *logos*, that is reason, as a distinctive characteristic of humans, a basic scope from which rationality can adopt diverse meanings according to the framework assumed.

For Broncano (1996) rationality is to use reason in a theoretical, practical, and evaluative proper way. It also means to employ reason in the adoption of beliefs, decisions, evaluations and norms. Also implies a proper usage of intelligence. From a biological standpoint, rationality has evolved from irrational to rational forms of information processing. This way, every phenomenological approximation to the matter is to be taken as provisional or, at least, as insufficient. Rationality also has a twofold facet, one subjective, one objective, one of the reasoner, one of the observer, inner and outer aspects. Rationality has also intersubjective, and normative aspects. Rationality is an evolutionary system of inner cognitive control within an ampler set of systems of neuro-biological controls. Rationality is an inference quality control system arising from representational capacities.

Although for centuries of occidental civilization, rationality has been a highly and firmly appraised concept, rationality is nowadays seen as a concept undergoing a severe crisis. Many think that what actually is in crisis is the classical conception of rationality, and that this conception must be *deconstructed*. For Rorty (1989), for example, the term *rational* presupposes no substantial sense of description but only of approval.

For the classical conception of rationality, a conception elaborated on modern rationalism, rationality must be firstly *unique* rejecting the idea, and the possibility of a plural rationality, and, secondly, it presupposes that the inferential links that rationality establishes must be *necessary. Necessity,* alike *impossibility,* and *contingency* are modal categories constituting the basement of logical rationality (López Alonso, 1998, 1999). So the classical concept of rationality presupposes that for any two independent reasoners sharing the same information at their disposal they should arrive necessarily at the same solution or conclusion if they actually use a rational procedure. It is supposed that rationality operates according to rules that are universal, and logically grounded, however this is an approach that restrains too much the rational powers of mind, which are basically inferential rather than conceptual. As alleged by Brown (1988) to operate according to rules that are logical, and universal constitutes the core prerequisite of the classical conception of rationality.

Contrary to these arguments, there have been different approaches recognizing the want for an ampler scope to include non-rational sources for the explanation of inferential processes taking place whether inside or outside the domain of science. This contrariety convoked also psychologists,

some of whom like Kahneman, Slovic, and Tversky (1982) promoted a new insight based on experimental evidence that showed logical errors as systematically committed by untrained reasoners. According to Johnson-Laird (1983, 1985) too there is no logical substrate to the supposed *mental logic* implied by Henle's, and Piaget's theories on human reasoning, but a linguistic ability to construct and learn *mental models* which constitute the *inferential pieces* mounted on the interchangeable meaning of the terms.

A first question is whether or not to resolve the implicit ambiguity of information is enough to eliminate inferential biases. Some irrational or illogical errors, and biases seem to be systematic and symptomatic. Some systematic biases and heuristics have been observed, and typified by Tversky, and Kahneman, as availability, and representativeness (1983) where logical errors like transgressing the *extension rule* and committing the *conjunction fallacy* are commonplace. Symptomatic contradictions as logical errors were also experimentally found by López Alonso (1991), and López Alonso, and Ricardi (1993) when evaluating the Test of Reasoning Coherence in a psychiatric sample. These authors found that irrationality may be a clear-cut symptom of thought inferential disorganization. In this case, ambiguity was more inferential than informational. The employment of this instrument (López Alonso, 1999, 2000) allowed to distinguish two different aspects concerning meaning, and reasoning, language communication and social representations; these two aspects are the difference between *literal meaning* and *inferential meaning*, a difference that helps to better understand rationality, and to explain, for example, why literal translations do usually fail. Later on, we shall return on this two meanings difference.

A second question is up to what point science, and scientists are exempt of meaning biases, and inferential heuristics such as those. New views on rationality shed a somewhat caricature appearance on its classical conception (like that of Descartes, and Leibniz) for overlooking rationality complexity and its variety of dimensions. In classical conception, rationality is tightly linked to objectivity and truth, a tie that has been systematically objected by skepticism. Criticisms against the *uniqueness* of reason have been growing on from different disciplines, both philosophical and cognitive. This represents an open attack to the implicit identity between rationality, and logic; although one might argue, for example, that rationality is unique, however logic is not. Anthropologist have alluded to the plurality of logics and cultural mentalities: Does it presuppose a plurality of *rationality* too, or not?

It has been also thought that rationality must be a *super-logic* that makes all logics only one, that rationality must be capable of transforming

one logic into another, and conversely, that rationality is a reversible, and transformable power beyond all logic. For all these assumptions we must first conceive rationality as a cognitive power, more than an epistemological one. Whatsoever this power could be, it must be always a mental power, a cognitive power of mind. A power to make explicit what is already implicit, to make declarative knowledge what is already a procedural knowledge, or, finally, a power to make explicit and declarative what pure inventive and discovery.

Reichenbach (1938) used Herschel's sharp distinction between *context of discovery*, and *context of justification* in science, claiming that philosophy of science should be concerned only with questions of confirmation and acceptance that belong in the context of justification, and that the topic of discovery should be relegated to psychology, and sociology. Some philosophers have resisted that restriction. Thagard (1988) rebuffs the distinction between the two above contexts arguing that the two blend together. Thagard argues that there is no need of a sharp division between logic, and psychology, since the link between theory discovery and justification comes through a form of a reasoning that Peirce (1992, 1994) called *abduction*. Abduction is inferring a hypothesis that provides the most possible explanation for us of some puzzling phenomenon. For Thagard, Peirce's abduction is not widely known by cognitive science researchers, although abduction is a pervasive cognitive phenomenon, both in science and in everyday life reasoning.

Abduction is as to choose a hypothesis to make coherent our thorough framework of information and evidence. Hypothesis formation is ubiquitous in everyday life as well as in science. Abduction could be studied as an attribution process. As Peirce noticed, and as psychologists such as Gregory (1970), and Rock (1983) have subsequently confirmed, abduction plays a main role even with relatively simple visual phenomena. Many visual stimuli are impoverished or ambiguous, yet people are adept at imposing a rational order on them by using abduction.

For Thagard, abduction, as a formation of explanatory hypotheses it is, is the primary means for introducing new theories. And, for us, abduction is a natural way of inference to impose a rational order into incongruent or incoherent information or unexpected puzzling observations. For Thagard, by using abduction new theoretical concepts can be formed as conceptual combinations. Meaning can develop as an inferential system. The concept of abduction is the cognitive basis we have adopted to develop our distinction of *inferential meaning* as from *literal meaning* in order to discern the rational and the irrational cognitive counterparts of science.

Peirce held that abduction is the standard form of setting up scientific hypotheses, and can count as the third kind of inference, together with induction and deduction. Since then, it has been stressed that what makes *A* probable is that it is the *best* explanation we can think of. Scientifically useful abduction is, then, the *inference to the best or most probable explanation*. Statistical inference, and decision is technically abductive in that sense (see Figure 1).

For us, inferences are a lot more than a mere set of sentences, and propositions. Inferences are processes of forming and conforming new propositions on a believability stance. We understand they are a platform to explain rationality from a cognitive scope, whether from outside or inside science, logic, and epistemology.

What is inference from a cognitive approach? As Sanford (1991) asserts, an inference is made whenever a reasoner, either human or machine, goes beyond the evidence given. Inferences occur in all kinds of understanding and reasoning. The result of an act of inference may be valid or not. Inferences may be made which are only likely to be the case, rather than necessarily the case. Inferences occur everywhere in perception, reasoning, understanding, and language comprehension.

In social cognition a great deal of work has been carried out on the question of *inferential patterns*, particularly in the explanation of events or states of affairs. This literature is generally known as *attribution theory* since it can be thought of as the study of how people assign blame or credit for situations to the people or things which happens in the world. Attributional inferences are often made in the absence of all of the relevant information, showing fundamental patterns or biases (Nisbett, & Ross, 1980), such as *typicality* (high consensus) and another one is the fundamental attribution error, which is to explain a person's behavior in terms of her dispositions, rather than in terms of environmental pressures on her. Another is the actor/observer bias: the tendency to make the fundamental error with others, but to explain our own behavior in terms of what the environment is doing to us.

Essaying a scope avoiding scientific biases, Newton-Smith (1987) tries to explain the rationality of the scientific change and non-change as the shift from one theory paradigm to another, when referring to science rationality. He attributes changes to rational internal factors or to non-rational external factors. Internal factors are rational because they depend on the inner rationality provided by divergent explanatory schemes. So he defines two models of scientific change depending on rationality and on non-rationality. Non-rationality changes depend on social, psychosocial influential

powers and tendencies of scientific communities. From the rationalist standpoint he defines, a particular scientific model declines as a consequence of another scientific model whose rationality power overthrows the rationality of the preceding model. From the standpoint of the non-rationalists change or non-change depend on the scientists' social prestige or any other external factor. Popper, and Lakatos are examples of rationalists. Kuhn, and Feyerabend, as examples of non-rationalist will tend to explain alleging causes other than rational requirements. *The most serious contend is the one asserting that every rational model contains implicit presuppositions that are unsustainable from its inner irrationality*. This is not a superfluous but a substantial claim. In this concern, the attacks against rationalist viewpoints may be either *apathetic* or *exalted* attacks. Apathetic attacks stem from whom accepts the ideal of rationality but concedes pessimistic allegations against its applicability. Exalted attacks, instead, come from who deny any possibility of rational change or sustainability. However, in both cases, rationality must be defined from the occult or implicit goals behind the intends of change or non-change argued as rational or irrational.

One aim of rationalists is that theories can be compared between, however irrationalists, like Kuhn, and Feyerabend, sustain the incommensurability of theories; this means that theories cannot be compared between. We will see that this incomparability depends and may be explained as the incomparability of inferential processes. The kind of noncomparison provided by theories incommensurability implies that theories are untranslatable in between by virtue of the different meanings and implications of even their commonplace terms. Although two competing theories use the same terms, the terms meanings in each theory have been altered in such a way (as non-rationalists assert) that the terms usage become a pun, or a mere play on words, from one theory to another. However, it is not a matter of logical incompatibility between, it is a matter of difficult or impossible translatability of the commonplace terms due -as we argue- to basic substantial changes in the inferential meaning of those commonplace terms. That is, we conclude, each theory is an isolated complex inferential system. This fact induces us to include a cognitive approach concerning the incidence of inference, and meaning formation within the theories spectrum. Would this help to better understand science rationality and better to discern and separate it from its irrational counterparts or its irrational blind processes? The incidence of inferences in meaning constructive processes is so powerful that it induced antiorthodox and irrationalist epistemologist to assert that facts or event observation depends on theory construction rather than theory depends on independent empirical observations.

We have recently obtained an experimental check on the incommensurability of inferential meanings as dissipative phenomenon diverging from the usual literal meanings of social commonplace concepts. That is, we have obtained results that allow us to explain cognitively the incommensurability of theories. This experimental check was obtained by using the Test of Reasoning Coherence.

Inferences seem to be constructive and creative processes growing divergently and arborescently in connection with meaning, and new forms of rationality. This is an issue necessarily calling not only for a deeper analysis of cognitive processes, but for the inclusion of the theories of complexity.

We have been checking that each theory is in itself a different inferential system, and that it is also a system of different inferential meanings for the same set of terms, however it is not necessarily a system with different literal basic meanings in their commonplace terms as probably presuppose the most radical antiorthodox or irrationalist epistemologist, who because of this extreme presupposition have been severely criticized by Newton-Smith. This author has alleged, in a fully justified way, that this extreme presupposition implies what he calls *the radical variation of meaning* what finally leads science into a way of total irrationality, a liminal situation where he asserts neither Newton nor Einstein could ever understand themselves not only on basic concepts like *mass*, but also in basic observational expressions like *see the needle is now marking four* or *the light is turning now green*, because that extreme irrationalist doctrine presupposes that terms like *needle, four* or *green* have also a different incommesurable meaning for each of the interlocutors. This extreme situation presupposes not only the incommensurability of both theoretical, and basic observational terms, but the impossibility of any way of rational understanding, and rational translatability of concepts and terms between reasoners or mere interlocutors.

From our experimental results using the TRC we were able to differentiate between two kinds of meanings for concepts and terms: the *literal meaning,* and the *inferential meaning*. *Literal meaning* is usually known and understandable, but *inferential meaning* deserves a further specification. Understanding ourselves means that we share at least a minimal commonplace literal meaning of the alluded terms, however we may not share in the same way the inferential implications of those terms when related between. That is, inferential relations keep constructing, and amplifying the meaning of the terms, but this time not literally but inferentially; that is *inferential meaning*.

The meaning of terms is not only defined by the basic literal acceptation, but it is also constructively built, and divergently used, and varied according to the alternative relations (or type of relations) that each terms holds with other terms. A mere relation between at least two terms amplifies, and changes unnoticeably, and divergently the meaning of each term, inferentially. Relations linking terms in between constitute the molecular ingredients to give shape to a characteristic inferential structure among terms, and consequently to imply a new inferential meaning for each of the related terms.

What we have found by means of the TRC is that in addition to, and behind the basic, usual, commonplace, easy understandable, and implicit literal meaning of terms there opens a new spectrum of individually divergent, but also typicality convergent inferential structures and consequently a new spectrum of in part divergent, and in part convergent inferential meanings for the same set of terms.

Inferences are basic processes of mind, and consequently inferential processes are more properly a cognitive matter than an epistemological matter. So, this allows us to understand that each scientific theory is a different inferential system, and a system of different inferential meanings, whatsoever the basic, literal meanings of the commonplace terms they employ. But this system divergence makes scientific theories incommensurable in between, since they are not logically contrastable nor comparable. Contradictions only take place within a same inferential system, but not between different inferential systems; this cognitively explaining the effective theory incommensurability proclaimed by antiorthodox and irrationalist epistomologist like Feyerabend, and Kuhn. However, we can be compatible or incompatible, as well as understandable or not at the level of basic literal meanings of terms, such as, perhaps not *mass*, but yes *needle*, *four* and *green.*

Figure 1
Formal correspondence between abduction and inferential meaning

Abduction *

The general form of abduction is:

(1) *D* is a collection of data;
(2) *H* (a hypothesis) would, if true, explain *D*;
(3) No other hypothesis can explain *D* as well as *H* does.
(4) Therefore, *H* is probably true.

Of course, abductive reasoning is common also in everyday life, whenever we try to find answers to questions why something is the case.

* Dictionary of Philosophy, Ed. Thomas Mautner, Penguin, 1997.

Inferential meaning

The proposed form of inferential meaning is:

(1) Let *L(A)* be the literal meaning of *A*, and *L(B)* the literal meaning of *B*;
(2) *R(i)* is the representative relation found between the meaning of *A* and the meaning of *B*;
(3) No other relation can explain the *A - B* relation as well as *R(i)* does.
(4) Therefore *A -R(i)- B* is a probable inferential meaning construed as representation upon the relation between *A* and *B*. So *I(A / B)* is the inferential meaning of *A* provided *B*, and *I(B / A)* is the inferential meaning of *B* provided *A*. The inferential meanings can be multiple for *N* concepts.

This way, this inferential representation is a common abduction in everyday life, whenever we are asked to define a term as from its relation with another term. Finally, the characteristic inferential structure of all the *R's* relations for a same set of literal terms provide different structures of inferential representations that can be seen as different and incommensurable theories about that same set of terms.

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