THE RELATION OF SIMILARITY AND THE COMMUNICATION OF SCIENCE

IOAN BIRIŞ*

Abstract: It has been said, not without some justification, that the knowledge process is, after all, a forward from "the identical to identical", which means, firstly, that the advance of knowledge involves the principle of reduction, and secondly, that every step forward in knowledge involves the relationship of similarity, since the operation of reduction can not function without it. But this means, further, that all scientific knowledge must assume the methodological principle of derivation of the future from the past. However, it also means that any communication of science is based on similarity to find those images to match – in a more accessible language – pictures of the more technical languages. Such a situation was acknowledged by some scientists but also by some philosophers of science. In the following we try to reconstruct a possible way of this approach.

Keywords: the relation of similarity in the scientific construction; scientific images; the communication of science; criteria of communication.

1. HERTZ'S DEMANDS REGARDING THE SCIENTIFIC IMAGES

In the German scientific and philosophical tradition, besides Kant and Neo-Kant's influences regarding the knowledge process, great influences had also the great physicists Helmholtz, Boltzmann, Hertz or Mach[1]. Particularly Hertz's idea that, in the end, the mechanics system is made of "images" which are structured in a deductive way, that these images are models of our representations about real things, was almost a "common good" among the German scientists and among the philosophers concerned with the theory of science. In the same direction were also Boltzmann's urges to consider physics' concepts and assertions as "mental images", models which describe the facts known through experience. As for Hertz, which becomes probably the most influential physicist in this direction, in his work *Die Prinzipien der Mechanik in neuem Zusammenhange dargestellt* (1894), he starts from the methodological request to derive the future from the past, pointing out the fact that we form our different interior images or symbols about the exterior objects, images which can be developed then by means of other images from the past, considered as models. With the significant indication that for the same objects one can have different images, which means, in contemporary terms, there is a "theoretical subdetermining of experience", Hertz foreshadowing in this way

* West University of Timişoara.

[1] See also Ioan Biriş, *The Formal Structure of Experience in Carnap's Aufbau*, Balkan Journal of Philosophy, vol. 2, No. 2, 2010.

successive generations of positivists[2], for whom, just like for Pierre Duhem, for example, the truth should not be sought in individual sentences, but larger or smaller systems of representations.

What status do these "pictures", these models have about real things? In Hertz's view they need to meet three requirements[3]: a) logical requirement, that is the requirement that such images are allowed (*zulässig*), that they do not contradict the principles of logic; b) empirical requirement, provided that the images are correct (*richtig*), are consistent with reality, with reality relations; c) pragmatic requirement, the requirement that images are appropriate (*zweckmässig*), are as simple as possible, not to contain unnecessary or even empty relations. If the first requirement can be determined uniquely by formal finding of how a picture breaches or not the principles of logic, and the second one can be established unequivocally also through experience, with the third requirement we are in a more delicate situation since the establishment of the appropriateness of an image is generally not an unequivocal decision process, but different decisions of researchers and only a gradual control of multiple images on the time axis can provide us a more appropriate image. One can notice from these requirements and conditioning of scientific models a special care of the German scientist (as a more general concern in the spirit of time) for logical purity of scientific knowledge, and simplicity of the theory together with careful experimental foundation. Means of new logic encouraged in this direction[4], control of experience was an objective pursued and formulated, and the idea of simplicity was somehow rooted in the mentality of naturalists as property of the real itself. Is no less true that the goal of simplicity, is more desirable, as it is difficult to obtain, "although apparently simple and unproblematic, subject to analysis, the idea of simplicity reveals many sides and issues initially unknown..."[5]. On a syntactic level – shows Constantin Grecu in the study on the idea of simplicity – we have three species of simplicity, the conceptual (linguistic or descriptive), postulational and structural simplicity (or logical); then on must take into consideration the semantical simplicity (the content of theories, the meaning of concepts, the value of truth) and pragmatic simplicity (which refers to the difficulty of inference of consequences of postulates).

Returning to the requirements established by Hertz, you can see his concern on the simplicity line in all three plans, syntactic (logical), semantic (experimental) and pragmatic. In the concrete way of his science, he noted, for example, that notions of "force" and "electricity" contain more correlations than is needed and

[2] Giovanni Boniolo, Maria Luisa Dalla Chiara et al., *Filosofia della scienza*, Raffaello Cortina Editore, Milano, 2002, p. 70.

[3] See Mircea Flonta, *Gânditorul singuratic. Critica şi practica filozofiei la Ludwig Wittgenstein*, Editura Humanitas, Bucureşti, 2008, p. 159.

[4] See Ioan Biriş, *Conceptele ştiinţei*, Editura Academiei Române, Bucureşti, 2010.

[5] Constantin Grecu, Aspecte ontologice, gnoselogice şi logice ale simplităţii, in vol. *Logică şi ontologie*, Editura Trei, Bucureşti, 1999, p. 325.

more they can support, and mechanics often presents itself under the appearance of three different systems with variable fundamental notions: a system is based on the notions of space, time, mass and force; another one has the fundamental concepts of space, time, mass and energy, the third is based only on the notions of space, time and mass. Of these, according to the requirement of simplicity, only the latter should be retained.

Then, naturally, science must not deviate from the principle of observability. In this sense Mach will appreciate that Hertz defines the primary concepts of mechanics (that is space, time and mass) in order to retain only what is really noticeable[6]. That is why Hertz abandoned the concept of force as a primary concept for mechanics, as it was imposed by Newton, since the notion of force raises aspects and issues that go beyond the sphere of observability.

Differences of vision between Newton and Hertz may be due to the underlying mathematical methodology, Newton, in the extension of Kepler, favors the methodology of utmost calculation of laying areas, volumes or lengths depending on the inertia of curved figures (although Newton is one of the discoverers of differential calculus), to Hertz's more important, for example, to establish the actual dependence of motion of bodies on the differential equations expressing the coordinates of the mass, the rates of exchange being seen as the functions of the independent variable change. If the first mathematical methodology favors the capture of an unit of an area or configuration, the second, differential calculus, especially highlights the dependency relationships within a configuration. Let us not forget that the science system is made up of "images", Hertz thinks.

How to get to these images? What is their foundation? Let us remember that the foundations of mathematics had passed through a deep crisis with non-Euclidean geometries discovery, that one had entered into a crisis of fundamentals of physics, some philosophers of science hoping to find a solid foundation of science in the soil of logic. However, paradoxes had appeared (especially highlighted by Russell). Here's why some tried other options too such as the psycho-physiological paradox in the line of Mach. A brilliant program in this direction was offered by Carnap, in his famous work *Der logische Aufbau der Welt* (1928).

2. THE RELATION OF SIMILARITY IN THE SCIENTIFIC CONSTRUCTION: FROM CARNAP TO QUINE

On the footsteps of Mach, Carnap considers – in *Aufbau der Welt*[7] – that the starting point in building scientific images should be the basic sensitive

[6] Giovanni Boniolo, Maria Luisa Dalla Chiara et al., *Filosofia della scienza*, p. 69.
[7] Rudolf Carnap, *Der logische Aufbau der Welt*, Meiner Verlag, Hamburg, 1998.

experiences, in their quality of original elements (Urelemente), but “elements” in the gestaltist sense, *i.e.* structures in which the emphasis is on relations. At the basis stands the relation of similarity as a background where the whole construction can begin as sensitive basic experiences can not be “reunited” if similarity misses.

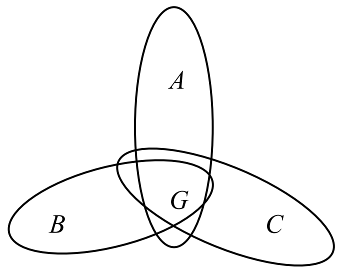
It is a dyadic relationship, interprets Moulines, namely: on the phenomenal temporal aspect of reality we have an asymmetric relation, *the memory* (subject or Turing machine can remember in moment *t* that they had a partially similar experience in moment *t–s*); structurally we have a symmetric relationship, the relationship of *partial similarity*, which is constitutive to sensitive qualities. The dyadic relationship of *memory of similarity* (Ähnlichkeitserinnerung) is thus the cornerstone of the entire construction. Taking this relationship, Quine will characterize it in the following terms: “Carnap’s fundamental relationship between elementary experiences is that of a *memory of similarity*, a relationship which I will note with *R*. An elementary experience, say *x*, is found in the relationship R with another basic experience, *y*, if *x* includes a recognition of *y* as partial similarity with *x*”[8]. Quine agrees in his 1995 work, along with other contemporary American philosophers, that Carnap’s project Aufbau is again of actuality and that the evolution of science and epistemology requires reconsideration of the stakes of the Viennese philosopher. Carnap did not need, Quine points out in his latest work, by the end of life, additional predicates to denote elementary experiences as an elementary experience may be in relation *R* with any other experience, ultimately with anything else. In Quine’s terminology, science stimuli are the very basic experiences of Carnap’s language.

In the constructionist theory of Aufbau, the objects (or concepts) in each level are “built” of objects (concepts) from the previous level. In this process one must take into account at least the following main aspects: a) basic level features, a level on which all other above levels are built; b) determination of forms of ascent by which we rise from one level to the next; c) investigation of how different types of objects can be constructed by repeated applications of upward forms; d) the form of the system resulted from such a construction. While the base level from which we start consists of extralogic entities, other levels are logical constructs, that is forms of rise in the construction, forms of the object and forms of the system. A system built in this way is not the classifier type, but one derivational, genealogic. Based on the relationship of similarity, the derivational process highlights the partial similarities, the circles of similarity, quality classes, partial identities, similarities between the qualities, sensory classes[9].

[8] W. V. O. Quine, *From Stimulus to Science*, Harvard University Press, Massachusetts/London, 1995, p. 10.

[9] More broadly on these issues see Ioan Biriş, *The Formal Structure of Experience in Carnap’s Aufbau*, Balkan Journal of Philosophy, vol. 2, No. 2, 2010.

In a graphical representation we can express – like Mario Bunge – classes as ensembles determined by a single property, and the gender as an intersection of classes, as in the figure below[10]:



(A, B, C = classes; G = the gender of classes A, B, C)

For a more nuanced understanding – underlines M. Bunge – one needs to establish the degrees of similarity and in the dual mode of dissimilarity and of differentiation. Two objects with a gender identity can have a degree of similarity, a weaker or stronger one, a superficial or profound one. One must specify the fact that the relationship of similarity should not be confused with that of equivalence, since similarity is reflexive and symmetric but not transitive[11]. Understood as a function, similarity can be expressed in a formal way as follows:

$$\sigma(x, y) = p(x) \cap p(y)$$

(σ = similarity; x, y = objects; p = property, quality)

In what the similarity degree is concerned, it can be calculated using the formula:

$$s(x, y) = \frac{|\sigma(x, y) \cap B|}{|p(x) \cup p(y) \cap B|}$$

(s = degree of similarity; B = finite subset of p)

In turn, the degree of dissimilarity can be established on the basis of the dissimilarity function, and on the relation of differentiation:

$$\delta(x, y) = p(x) \cup p(y) - \sigma(x, y)$$

(where δ = dissimilarity)

Starting from this function, the dissimilarity degree can be established with the formula:

[10] Mario Bunge, *Ontology,* Reidel Publishing Company, Dordrecht-Holland/Boston-USA, 1977, p. 143.

[11] Max Kistler, Le concept de gén identité chez Carnap et Russell, in vol. Sandra Laugier (ed.), *Carnap et la construction logique du monde*, Vrin, Paris, 2001, p. 166.

$$d = \frac{|\delta(x, y)|}{|p(x) \cup p(y)|}$$

(where d = degree of dissimilarity)

Naturally, the values of $s(x, y)$ and those of $d(x, y)$ are found in the range <0, 1>. But beyond the accuracy obtainable in the calculation of similarity, that which in the philosophical plan remains questionable is the property of transitivity or non-transitivity of similarity. Both for Carnap and Quine assumptions seem to work (which are neither logical nor empirical) of at least local convergence of a quality series of continuity, monotony and homogeneity[12]. Starting from here, in the opinion of J. Ph. Narboux, Goodman's criticism at Carnap's construction based on the similarity relation shuts *Aufbau* in a dilemma: or the predicate of similarity is considered transitive as Carnap uses, and then you have to accept that the approach is circular, or it is non-transitive (as suggested by Goodman and, in the same line, Bunge, as we saw above), in which case the construction system is questioned. Quine manages to avoid the dilemma by postulating the following perspective: if by the abstract operation one does not determine something specific (the abstracting selects, retains something, does not determine) it results that one can give up its procedures for at the level of primitive induction we already have a generalization a non-formal one, not "abstract".

From Carnap, Quine will emphasize that in the primitive sense of similarity we find a certain complexity of its structure: *a* is more similar to *b* than *c*. This means that within this structure, on the similarity of substance between *a, b* and *c*, there are differences of degree, the similarity between *a* and *b* is greater than that between *a* and *c*. What does this structure mean? It means that our sensitive experience masters to a certain extent the individuation situation, that the entities *a*, *b* and *c* are circumscribed and differentiated on the similarity field. How does this happen? In the primitive induction of we are already doing some generalizations that can be seen in the process of ostensive learning. In this sense Quine objects to Wittgenstein that it is not the same thing acquiring on an ostensive way the reddish-brown color (sepia) with what represents a rabbit, for example. Since Quine argues, it's a big difference between "sepia" (color) and "rabbit", because while the "sepia" is a mass term (such as "water", for example), "rabbit" is a term of divided reference. And is clear that the split reference can not be seized in the absence of the principle of individuation[13].

This observation is very important for Quine when dealing natural kinds (Natural Kinds). A crucial question that arises is: can the individuation problem be

[12] Jean-Philippe Narboux, La construction: abstraction ou schématisation? Quine et Goodman lecteurs de l'Aufbau, in vol. Sandra Laugier (ed.), *Carnap et la construction logique du monde*, p. 160.

[13] W. V. O. Quine, *Ontological Relativity and Other Essays*, Columbia University Press, New York, 1969, p. 31.

mastered by ostensive learning? If we consider the similarity structure mentioned above (*a* is more similar to *b* than *c*), some believe – Quine points out – that this structure is very complex, as the likeness depends fundamentally on the aspects under which things are seen, if it's similarity in terms of color, shape, etc. In this respect, learning, for example, through an ostensive way of color "yellow" will depend on the fact that previously we know in some way what color means. However we need a "general rule of resemblance" of comparative similarity, of course. Such a "standard of similarity" – says Quine – is innate (*A standard of similarity is in some sense innate. This point is not against empiricism, it is a commonplace of Behavioral psychology*). Such a position of Quine may raise some perplexities among empiricists, but the American philosopher, wishes to clarify that after all, empiricism can accommodate with the thesis of some "innate" standards as the psychology of behavior accepts them.

In line with his naturalism, Quine thus supports a "innate space of qualities" necessary space for all forms of learning, but which can not be taught, since it is innate. Such "spaces" represent some conditions of possibility for different forms of learning, which means that ostensive learning alone can not control the principle of individuation. We thus answer the question above. The "innate" character of the similarity standard can be truly and accurately interpreted, Quine believes, in terms of animal and human behavior. For example, the different expectations of the animals, their salivation in the presence of stimuli, avoidance movements in certain situations, etc. are clearly dependent on their appreciation of similarity. Then induction itself depends on the similarity assessment, and the ostensive learning of different words is nothing more than a default case of induction. But how do you explain that innate quality spaces are matched in the induction process with the natural situations, with what exists in external reality? Quine's answer is in the line of Darwin: innate spaces that have the greatest success in inductive process are those that tend to predominate through natural selection. The naturalistic position is very clearly recognized, and from this position Quine will argue that philosophy should not be a propedeutic for science, but to be in the same continuum with science, epistemology being thus part of biology.

Quine agrees that induction may have obvious defects. Naturally, colors impress people, Hempel was impressed by the "black crows", Goodman by "green emeralds", etc., but on a cosmic scale what represents a color contrast may be of a secondary importance. If in the inner qualities space the color can have a crucial role at a cosmic scale it may be indistinct in the circles of similarity and thus it can not form natural kinds. No doubt the color is very helpful for man in the purchase of food, at the level of which, based on induction, our quality space value inclined towards colours will survive. But if at this level the colors contrast can be crucial to human activity, that color contrast can be insignificant for the most comprehensive level of theoretical science. That is why the innate similarity which is helpful for a particular sphere of activity will become an impediment to another area. But according to scientific objectives the standards of similarity may change. Through the test-and-error process different things can be regrouped in different genders or new species when one uses better inductions than the old ones. A classic example of this is the exclusion at a certain of whales from the fish class.

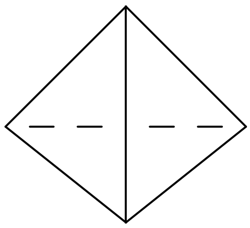
There is, therefore, Quine assures us a certain progress of similarity standards. When we define similarity based only on animal and human behavior we have not a definition to please the science, still we can not yet say what actually means that *a* is more similar to *b* than *c*. But for a chemist, for example, a higher similarity between two molecules can be expressed more precisely by the fact that two molecules have an equal number of atoms or equal atomic weight, and the modern physicist can call the theory of elementary particles located in space-time, and the biologist can discuss degrees of similarity in terms of genres etc. After all, even common-sense language about beliefs and opinions could be replaced with a scientifically one about the neuronal determinants of behavior, as for example the qualitative term "soluble" may be replaced by statements about molecular structure. In general, replacing a discussion about dispositions with one about structures is related to Quine's[14] strategy, the same as for Carnap in the Aufbau.

3. BACK TO OBJECTS! COGNITIVE THEORIES

Carnap-Quine line of philosophizing on the structural description of knowledge experience based on similarity relation and quality spaces seems to be increasingly supported in recent years also by the research from a cognitive perspective. Recent studies in this area of investigations point out that different concepts of knowledge are structured and that we speak of *conceptual spaces* (of concepts organized in the space of colors, of sounds, etc.). Any conceptual space contains a certain number of qualitative dimensions and these dimensions can have both a sensory character and a non-sensory one, they form the context in which we can assign objects of knowledge and relations between them. Each quality dimension has a structure which may be of a geometric, topological, order nature. For example, the dimension of time can be modeled one-dimensional as an isomorphic structure with the line of real numbers, at least in Western culture (in other cultures this structure can be shaped circulary or in other ways). An illustrative example can be the structure of the taste space[15]:

[14] J. J. C. Smart, "Quine's Philosophy of Science", in vol. Donald Davidson and Jaakko Hintikka (eds.), *Words and Objections. Essays on the Work of W. V. Quine*, D. Reidel Publishing Company/ Dordreht-Holland, 1969, p. 12.

[15] Peter Gärdenfors, *Symbolic, Conceptual and Subconceptual Representations*, Cognitive Science, Lund University, Sweden, p. 9 (http://courses.media.mit.edu/2002fall/mas962/MAS962/ gardenfors% 204.1.pdf, 3/16/2009).



To those seen up here, where the emphasis is always on ways of describing objects, their properties, one can raise a question of principle: can't one proceed the other way around? One can not start directly from objects, and not from their description? Such questions are taken seriously by the cognitivists. But when we want to start from objects, another question immediately arises: the scientific image, scientific concept must have as a reviewer a general type or an individual, a single reviewer?

Unlike Wittgenstein's solution – the family resemblances – the cognitivist orientation in recent years raises the question of the "typical effect" theorized for the first time by Eleanor Rösch[16]. In this perspective, a reviewer can be identified as a member of a class if it matches the representative type of that class. In other words, it is not only about family resemblances, as in Wittgenstein's conception, where similarities are sufficient if they fall within the same family, even if less important, less significant, but one should consider global similarities, the typical for a class or a gender. This means that between members of the reference there is a clear discrimination, discrimination which the classical theory blurred.

In fact, say the cognitivists, some members of the field concept can represent the concept better then the others. So the typical representative properties may apply to most members of a class, but not all, as alleged by the classical theory. But there are cases when, in the absence of typical properties or those related to the core concept, the reviewer is placed without difficulty in its class. Famous in this respect is the example given by Ziff[17] with the tiger that has only three paws. Although in the core concept of tiger enters the defining property of "quadruped" the actual copy of tiger with only three paws is identified as a member of the class of tigers without difficulty.

Classical theory encountered further complications. Aiming at an ontological support of concepts, from classical theory one can ask questions like the following: what status is given to the concept when the determination of the properties in its

[16] Eleanor Rosch, Cognitive representation of semantic categories, in *Journal of Experimental Psychology*, 104, 1975.

[17] Paul Ziff, *Semantic Analysis*, Ithaca, Cornell University Press, 1960.

content is made on an ontological base? Can we still say that it is a mental entity? Then, if we consider that the determination of these properties is made starting from the intension of the concept, how will we proceed when the intension is not sufficient to determine whether an object belongs or not to a class? In Sylvand Benjamin's opinion, according to classical theory, the concept as definition can be expressed as follows

Object x is expressed by the concept of α if and only if it possesses characteristics

$$\Phi \{c1, \ldots, cn\}.$$

That is concept α is a function of attribution defined on two values, so the object x has or does not possess these characteristics:

$$\alpha \rightarrow 0, 1$$

To conclude: $$f: x \rightarrow \alpha \begin{cases} 1 \text{ only if } x \text{ possesses } \Phi \\ 0 \text{ if } x \text{ does not possess } \Phi \end{cases}$$

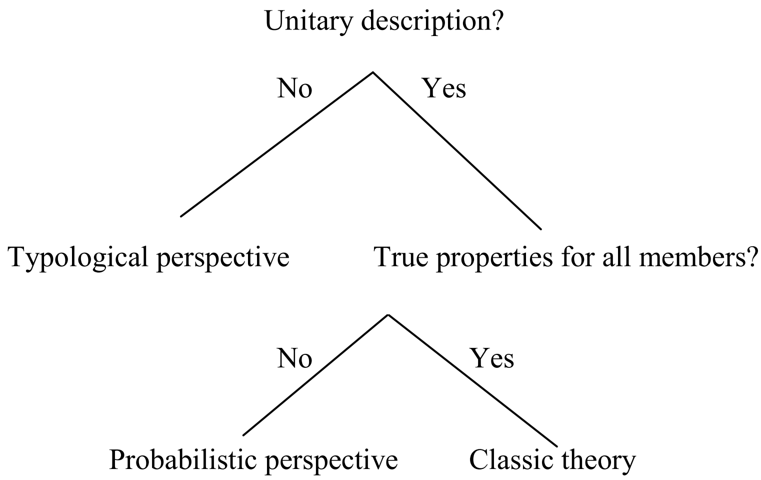
This function is basically a categorizing function[18]. Since Φ characteristics must be necessary and sufficient that any object must be categorized in one class at the same level:

$$\forall \alpha \ \forall x (x \in \alpha \vee x \notin \alpha)$$

In comparison with classical theory one can raise two fundamental questions: 1) there is only one description or a unitary description for all members of a class of objects?; 2) the properties specified in the unified description are true for all class members? Classical theory answer yes to both questions. But we have seen that cognitivist studies point out that among the members of a class of objects, and between reviewers within the scope of a concept are usually some differences, so not all the members of a class are representative to the same extent and the specific properties are found in certain degrees of probability in a class member or another. Therefore, from a probabilistic perspective, you can answer yes to the first question but not to the second. And from a typological perspective (view sample) one can not answer affirmatively to the first question, making superfluous the second question. This situation can be rendered more expressively in the following figure[19]:

[18] Benjamin Sylvand, *Concept et Changement de concept*, Université Paris IV – Sorbonne, 2005, p. 71.

[19] Edward E. Smith and Douglas L. Medin, *Categories and Concepts*, Harvard University Press, Cambridge, Massachusetts/London, England, 1981, pp. 3–4.



But we have seen that the typological theory also has problems with categorization of objects. That is way, also in the cognitivism, one has called the prototype theory. This theory, developed mainly by Eleanor Rösch, is, in the opinion of some authors, an effort to refining the theory of typology. The model or prototype has as a leading role the recognition and identification of objects, which means that the body would have a prior representation of the object[20]. But we can ask whether this representation is iconic or procedural, if it is inferred from conduct or otherwise obtained. Either way, the theory of the prototypes relies on the calculation of similarities for the objects subsumed to a concept, calculation which can be quite accurate, as we have already shown.

Moreover, the similarity calculation implies the idea of a point of balance between the objects belonging to a concept, Nash type equilibrium point that maximizes the aggregation of different properties just in the case of the prototype, the equilibrium point being thus the representative of the concept. If in the classical theory of concepts, the belonging of an object to a concept was determined by a strict list of properties deemed necessary and sufficient, with prototype theory this requirement is much relaxed, making room for a space of gradations, of the less precise measurements, an object may be quite in a position to belong in a higher or lower degree to a certain concept, depending on proximity to the prototype[21]. One speaks then of a "threshold" input in concept, a minimum limit depending on which one can assess whether a particular object may or may not be subsumed to the concept. Noting that membership in this case is not assembled, but is based on the degree of similarity, thus calling into question the transitivity of the properties, and of prototypes.

[20] George Vignaux, *Les sciences cognitives. Une introduction*, Éditions la Découverte, Paris, 1992, p. 188.

[21] Benjamin Sylvand, *op. cit.*, p. 88.

Perhaps it is more about *mental images* rather than concepts? Are our senses a sort of "specialized detectors"? Understanding to retain what is valuable in prototype theory, Jesse Prinz proposes the term "proxytype" as a kind of meta-set, *i.e.* set of sets of properties, which is enough to trigger detection of concept. For example, for proxytype "dog", we have properties like "fur", "barking" and "body". The proxytype can be instantiated in this case through the assembly of four components: all components detected by the "fur" and "barking"; all components detected by the "fur" and "body", all components detected by the "body" and "barking", all components detected by these representations. Unfortunately, in this case we are rather at a perceptive level, not at a conceptual level. Thing generally valid for the cognitivist orientation.

4. CONCLUSIONS: POSSIBLE CRITERIA FOR COMMUNICATING SCIENCE

Cognitivist orientation remains essentially at a perceptual level, but points out the importance of the object for knowledge and for establishing the field of concepts (through categorization). Science can not remain in the perceptive, it needs theorization, namely treating concepts as theories. Taking into account the suggestions made in the line of development supported by Hertz, Carnap and Quine one can formulate the following principles for the communication of science: 1) The existence of an isomorphic relationship between the scientific image (theory) and reality; 2) Existence of an isomorphic relation between the scientific image and the communicated image; 3) Ascension forms from reality (R) to the scientific image (IS) and communicated image (CI) are transitive.

Based on these principles, we believe that one can outline the following criteria for evaluating the scientific communication:

1. *Topological isomorphy*: scientific image elements (technical, for practitioners) to meet the elements of reality, and elements of the communicated image (for non-specialists) to have the corresponding elements in the scientific image (isomorphy of places);

2. *Relational isomorphy*: the relations between elements of the scientific image should be isomorphic with the relations between elements of reality and the relations between the elements in the communicated image isomorphic with the relations between elements of the scientific image;

3. *Classial isomorphy* (where isomorphy between elements is not possible or it is not significant): to what extent a class or structure can be projected on other class, widely, to what extent a predicate can be designed (from IS to IC) (*i.e.*, the predicate of "quarq" first appeared in astrophysics, could not be taught in quantum physics until the predicate of "subatominc particle" had not occurred);

4. *The ontic condition*: "the elements" of reality investigated are extralogical entities;

5. *Logical condition*: images constructed should be allowed, that is they do not contradict the principles of logic;

6. *The empirical condition*: provided the built images are correct, that is in line with reality;

7. *Pragmatic condition*: images constructed should be adequate, that is as simple as possible (simplicity criterion) not to contain superfluous elements and relations;

8. *Transitivity*: IC concepts are built from concepts of IS (based on similarity relation and the metaphorical construction);

9. *Plurality of potential models*: the extent to which the IC construction allows repeated application of transition from IS to CI (based on similarity, transitivity and metaphorical construction) resulting in more potential models of IC;

10. *Metaphorical effectiveness of IC* (examples, metaphors in mathematics: sets are containers; functions are curves; the logical independence is geometric orthogonality; recurrence is circularity etc.).

REFERENCES

1. Biriş, I. (2010). *The Formal Structure of Experience in Carnap's Aufbau*, Balkan Journal of Philosophy, vol. 2, No. 2.
2. Biriş, I. (2010). *Conceptele ştiinţei*, Editura Academiei Române, Bucureşti.
3. Boniolo, G., Dalla Chiara, M. L. et al. (2002). *Filosofia della scienza*, Raffaello Cortina Editore, Milano.
4. Bunge, M. (1977). *Ontology,* Reidel Publishing Company, Dordrecht-Holland/Boston-USA.
5. Carnap, R. (1998). *Der logische Aufbau der Welt*, Meiner Verlag, Hamburg.
6. Flonta, M. (2008). *Gânditorul singuratic. Critica şi practica filozofiei la Ludwig Wittgenstein*, Editura Humanitas, Bucureşti.
7. Gärdenfors, P. (2002). *Simbolic, Conceptual and Subconceptual Representations*, Cognitive Science, Lund University, Sweden, (http://courses.media.mit.edu/2002fall/mas962/MAS962/gardenfors%204.1.pdf, 3/16/2009).
8. Grecu, C. (1999). Aspecte ontologice, gnoselogice şi logice ale simplităţii, in vol. *Logică şi ontologie*, Editura Trei, Bucureşti.
9. Kistler, M. (2001). Le concept de génidentité chez Carnap et Russell, in vol. Sandra Laugier (ed.), *Carnap et la construction logique du monde*, Vrin, Paris.
10. Narboux, J. Ph. (2001). La construction: abstraction ou schématisation? Quine et Goodman lecteurs de l'Aufbau, in vol. Sandra Laugier (ed.), *Carnap et la construction logique du monde*, Vrin, Paris.
11. Quine, W. V. O. (1969). *Ontological Relativity and Other Essays*, Columbia University Press, New York.
12. Quine, W. V. O. (1995). *From Stimulus to Science*, Harvard University Press, Massachusetts/ London.
13. Rosch, E. (1975). Cognitive representation of semantic categories, in *Journal of Experimental Psychology*.
14. Smart, J. J. C. (1969). "Quine's Philosophy of Science", in vol. Donald Davidson and Jaakko Hintikka (eds.), *Words and Objections. Essays on the Work of W. V. Quine*, D. Reidel Publishing Company/Dordreht-Holland.

15. Smith, E., Medin, D. L. (1981). *Categories and Concepts*, Harvard University Press, Cambridge, Massachusetts/London, England.
16. Sylvand, B. (2005). *Concept et Changement de concept*, Université Paris IV – Sorbonne.
17. Vignaux, G. (1992). *Les sciences cognitives. Une introduction*, Éditions la Découverte, Paris.
18. Ziff, P. (1960). *Semantic Analysis*, Ithaca, Cornell University Press.