A Formal Framework for the Structural Analysis of Values in Science*

Un marco formal para el análisis estructural de los valores en la ciencia

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Abstract

A framework for formally describing and analyzing values in science from a structuralist standpoint is presented. The notion of value outlook from Lacey's and Mariconda's Model of Interaction between Science and Values (MI-SV) proves useful as a general starting point, although the structure of a value outlook is viewed here under much more formal and "microscopic" lights. The framework is developed in a stepwise fashion, from the general notion of value up to the notion of value judgement, and from the individual to the collective level. A few of its structural aspects, such the interconnected and holistic nature of scientific axiology, are discussed. The networked nature of the proposal is highlighted, and it is shown how it might illuminate various aspects of value kinematics and dynamics in scientific knowledge. It is suggested that the view presented here could provide more substantial grounds for the "pragmatic turn" in Structuralist Metatheory than has been the case until now. Some open problems and pending tasks for the view presented here are also pointed out.

Keywords: values - structuralist metatheory - value holism - Hugh Lacey - model of interaction between science and values

Resumen

Se presenta un marco de referencia formal para describir y analizar los valores en la ciencia desde un punto de vista estructuralista. La noción de perspectiva de valor del Modelo de Interacción entre Ciencia y Valores de Lacey y Mariconda resulta útil como un punto de partida en sentido general, aunque la estructura de una perspectiva de valor se entiende aquí bajo una luz mucho más formal y "microscópica". El referencial es desarrollado poco a poco, desde la noción general de valor hasta la noción de juicio de valor, y desde el nivel individual hasta el colectivo. Se discuten algunos de sus aspectos estructurales, como la naturaleza interconectada y holística de la axiología científica. Se destaca el carácter de red de la propuesta presentada, y se muestra cómo ella podría arrojar luz sobre varios aspectos de la cinemática y de la dinámica de los valores en el conocimiento científico. Se hace la sugerencia de que un enfoque como el presentado acá podría proporcionar una fundamentación más substantiva para el "giro pragmático" de la metateoría estructuralista de la de que se dispone hasta el día de hoy. Se apuntan algunos problemas que todavía quedan abiertos y tareas futuras para el enfoque.

Palabras clave: valores - metateoría estructuralista - holismo de valores - Hugh Lacey - modelo de interacción entre ciencia y valores

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* Received: 15 July 2021. Accepted in revised version: 13 September 2021.

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§ Elaboration of this work was partially supported by grant No. 455562/2014-8 from National Council for Scientific and Technological Development (CNPq) for VAB and a doctoral leave from Universidade Federal do ABC for LLG. A very early version of some of the ideas put forth here was presented and discussed as part of a paper read by VAB and LLG at the Annual Meeting of the International Society for the Philosophy of Chemistry in Rio de Janeiro, Brazil, in 2015. We are thankful to the audience for the questions raised. We are also grateful to the members of the Seminar Group "Metateoria Estruturalista, Filosofia da Ciência e Metafilosofia" coordinated by VAB at USP, where some of the ideas were discussed.

Metatheoria 12(1)(2021): 19-30. ISSN 1853-2322. eISSN 1853-2330.

1. Introduction

In this work we propose a framework for formally describing value outlooks in scientific knowledge, from the point of view of Structuralist Metatheory (from now on indicated as SMT). An adequate general preliminary setting for our project of formalizing axiological structures in science is provided by another metascientific model, namely, Hugh Lacey's and Pablo Mariconda's Model of Interaction between Science and Values (from now on, MI-SV). However, our interest rests in looking for a much more "microscopic" and structural/formal view of value outlooks than is envisaged by Lacey and Mariconda, and our proposal reflects this. We develop the framework in a stepwise fashion, from the notion of value up to the notion of value judgement, and from the individual to the collective level. We also make a few general considerations as regards the properties of value outlooks. In particular, we discuss the interconnected and holistic nature of scientific axiology, with both affinity and tension constraints distributed throughout, as well as the networked, multi-layered nature of the epistemological setting of the framework. We believe that being able to clearly formulate and reconstruct value outlooks is a necessary preliminary step towards the investigation of the structure, kinematics and dynamics of values in science, with a view to ultimately taking them into account as genuinely dynamical factors that guide theory choices, conceptual change and research decisions in a general philosophical picture of scientific rationality. Also, the availability of a framework and a mode of description such as the presented here will open the possibility of fulfilling in a substantial way the still unfinished, decades-old project of a "pragmatic turn" of structuralism, introducing notions such as "scientific community" into SMT in an organic and substantive way, and ultimately allowing for a definite formulation of the so-called "pragmatic" notions such as "pragmatically enriched theory-net", as well as pragmatic cognitive attitudes such as "holding a theory", and so on. The framework presented here is still in its early stages of development; it is reasonable to assume that further refinements will be needed. In conclusion, certain pending tasks and challenges will be pointed out.

2. Structuralist metatheory and pragmatic notions

Structuralist metatheory is a very fruitful perspective on the structure and dynamics of scientific theories. About a hundred of historical case-studies have been reconstructed and analyzed along the lines of SMT, about episodes from many scientific disciplines and various historical periods. 3.

Let us review briefly the main elements of SMT. Here we follow the standard treatments (e.g. Balzer, Moulines & Sneed 2012). Theories are viewed (synchronically) as *theory-nets* (usually denoted generically by **N**) composed of *theory-elements* (usually denoted by **T**) connected by *specialization relations*. Theory-elements are the smallest epistemic units of analysis considered in SMT, and are defined in terms of classes of potential models $\mathbf{M}_{\mathrm{p}}$, partial models $\mathbf{M}_{\mathrm{pp}}$ and full models **M**. These classes of models, plus constraints and links, constitute the core **K** of **T**, and this, together with the class of intended applications **I**, form theory-element **T**. We take the term "epistemic unit" to mean a symbolic construct that scientists are able to have cognitive attitudes about. Among such cognitive attitudes we can mention the following: acceptance and pursuit (see Laudan 2011), belief (standard cognitive attitude in most of contemporary epistemology, albeit variously defined), doubt (a classic in ancient and modern epistemology, particularly in skeptical contexts), "intending to apply" a theory and "admitting" it

(Balzer, Moulines & Sneed 2012, pp. 273-274), "holding" a theory (Stegmüller 1979, p. 29), and the trio "holding-adoption-endorsement" (Lacey 2015).

Until now, values have been rarely, if ever, mentioned either in the standard general structuralist account of theories or in the structuralist case studies (with the exception of some recent metatheoretical work by Luis Miguel Peris-Viñé 2018). However, values constitute one of the kinds of elements that can play a genuinely dynamic role in scientific knowledge and scientific practice, acting as propellers or engines of theoretical choices, conceptual changes, experimental decisions, and so on. In order to build a richer philosophical account of scientific knowledge — one that has a prospect of being more powerful and robust as an interpretive historiographical tool — we think that an effort towards bringing values to bear on the structuralist picture is in order.

In the "pragmatically enriched" mode, as the structuralist jargon goes, we find notions such as "scientific community" (indicated by **SC**), "scientific generation" (indicated by **G**), "historical interval", and definitions such as the following ones (here we follow e.g. Stegmüller 1979, §3, Moulines 1982, Chap. 3.3, Balzer, Moulines & Sneed 2012, Secs. V.1, V.2):

Definition. **X** is a *pragmatically enriched theory-element* iff there exist **T**, **SC**, **h** and **G** such that:

(1) $\mathbf{X} = \langle \mathbf{T}, \mathbf{SC}, \mathbf{h}, \mathbf{G} \rangle$;
(2) **T** is a theory-element, $\mathbf{T} = \langle \mathbf{K}, \mathbf{I} \rangle$;
(3) **SC** is a scientific community;
(4) **h** is an historical interval;
(5) **G** is a generation from **SC** during **h**;
(6) **G** has the intention of applying **K** to **I**.

Definition. $\mathbf{X} = \langle |\mathbf{N}|, \leq \rangle$ is a *pragmatically enriched theory-net* iff:

(1) $|\mathbf{N}|$ is a finite set of pragmatically enriched theory-elements;
(2) $\forall \langle \mathbf{T}, \mathbf{SC}, \mathbf{h}, \mathbf{G} \rangle, \langle \mathbf{T}', \mathbf{SC}', \mathbf{h}', \mathbf{G}' \rangle \in |\mathbf{N}|$ ($\mathbf{SC} = \mathbf{SC}'$, $\mathbf{h} = \mathbf{h}'$ and $\mathbf{G} = \mathbf{G}'$);
(3) $\leq \subseteq |\mathbf{N}| \times |\mathbf{N}|$;
(4) $\forall \langle \mathbf{T}, \mathbf{SC}, \mathbf{h}, \mathbf{G} \rangle \leq \langle \mathbf{T}', \mathbf{SC}', \mathbf{h}', \mathbf{G}' \rangle \Leftrightarrow$ **T** is a specialization of **T**'.

Definitions such as these are then used in order to define further notions such as "pragmatically enriched theory-evolutions", "progressive theory-evolutions", "Kuhnian paradigm for a theory-evolution", and so on (see Stegmüller 1979, pp. 32-33, Moulines 1982, pp. 282-283, Balzer, Moulines & Sneed 2012, pp. 174ff).

It is not difficult to see why criticism has been levelled at the manner in which SMT attempts to include pragmatic notions such as the "scientific community" **SC** (see e.g. Ibarra & Mormann 2010). The way it is usually done, it looks like the mere addition of a label rather than an organic conceptual refinement with a substantive content within the metascientific picture. The pragmatic notions seem curiously lacking in connections — in particular, connections of an epistemological and ethical sort — with the rest of the metascientific conceptual network. They seem to have an *ad hoc* character, being a terminological convention at best. Lip service is paid to the idea that "scientific communities and generations should be taken into account", but there is no talk of the specific *role* **SC** and **G** play either in constituting the body of scientific knowledge, or in having cognitive attitudes towards it, such as "*intending* to apply a theory-core **K**", "*acknowledging* certain elements of **I** as paradigmatic", and "*admitting* a certain proposition *p*" (Balzer, Moulines & Sneed 2012, pp. 273-274).

The "pragmatic" definitions, as they stand are, then, little more than symbolic abbreviations for informal notions — as in, e.g. "**SC** *stands for* 'scientific community'" — that are left mostly unanalyzed from a philosophical point of view. One could ask: *what* in the nature, content and texture of scientific knowledge *does* depend on whether it is a certain scientific community or scientific generation that is the *collective epistemic subject* that "has" a theory, "holds" it, or "intends" to apply it — as opposed to what would be the case in a disembodied, agent-less reconstruction?

3. Restriction and selection strategies

Lacey has been elaborating since the late 1990s a view of scientific knowledge as being developed and evaluated under certain research strategies, namely, large structures that, among other things, are able to restrict the kind of theories which can be formulated and to select what kind of empirical data can be used as such. The parameters for such a task of restriction and selection are given by the values shared by the scientific community, which can be either social or cognitive. Social values are constitutive of social structures, shared by a community that is larger than the scientific one and are related to an understanding of how society should be organized, and what goals it should pursue. Cognitive values are shared by the scientific community, and they are related to how scientific research should be conducted and what goals it should pursue. Values are instantiated in the knowledge-bearers (e.g. scientific theories, models, and so on). (As regards the distinction between both kinds of values, see Lacey 2010, Chapter 11.) When we focus on the research strategies that underlie a multitude of scientific developments it must be clear that we are not dealing with something complete and finished, but rather with something that is of a dynamic nature and is subject to modification.

The main epistemic unit of the MI-SV model (cf. Lacey 2008, 2010, Lacey & Mariconda 2014a, 2014b) is the so-called *restriction and selection strategy*. Here, we shall use a "neologized" notation that is slightly different from that adopted by the authors, but which is, nevertheless, compatible with the original model. A restriction and selection strategy (indicated by **S**) can be conceived as a structure, a 5-uple

$$\mathbf{S} = \langle \mathbf{T}, \mathfrak{T}, \mathbf{E}, \mathfrak{E}, \mathbf{V} \rangle.$$

Let us have a look at the constitution of this structure. **T** is a set of *theories* — where this term includes theory-elements and theory-nets. **E** is the "*empirical basis*", or the corpus of empirical information (the input from the world) **T** is confronted with —to be construed in terms of *models of data* (see Balzer 1997, Chap. 1), so as to include quantitative data, systematic qualitative observations, problem-situations, error margins, and so on.

The constitution of **T** and **E** is not a wholly arbitrary matter, but it's subjected to certain *constraints* within **S**. Now (again neologizing Lacey's proposal) $\mathfrak{T}$ is a class of evaluative constraints on theories (or *restrictors*), that specify which types of theories **T** must be built, preferred and accepted. $\mathfrak{E}$ is a class of evaluative constraints over empirical data (or *selectors*), specifying which types of data are relevant for the theories **T**. Notice that **E** does not presuppose anything like a "pure observation language" or a "neutral experience", neither does it point towards it: in fact, the selectors $\mathfrak{E}$ constitute one possible way to express the *theory-ladeness of observation* in science (although it is not the only one).

Lacey's general analysis (Lacey 2008) concludes that, since the 17th century, there has been a strong tendency to ground scientific activity on de-contextualizing strategies, a tendency that has only increased during the 20th century. According to him, the value of control over Nature plays a paramount role in such strategies, which set as the main goal of scientific activity the investigation of

the properly *material* possibilities of objects and their turning of objects of inquiry into *useful* objects to humankind.[1] A consequence of the prevalence of such a strategy is an approach that seeks to map in a *quantitative* and controllable way the objects up to their smallest details, and mostly considers them apart from most real-world, complex and unpredictable interactions with the environment or other objects — in short, a *de-contextualizing* approach.

4. Value outlooks

How do constraints $\mathfrak{T}$ and selectors $\mathfrak{E}$ work in a Laceyian research strategy? Ultimately, they are an expression of the ongoing continuous operation of *values* in scientific activity, constraining the building of the network of scientific knowledge. In order to capture this, one introduces the remaining component of **S**, indicated by **V**, called a *value outlook*, which is in fact a triple

$$\mathbf{V} = \{VC, VS, \Gamma, A\},$$

where VC is the set of *cognitive values*, VS is the set of *social values*, Γ is a function that assigns *relative weights* to the values, and A is a class of *affinity relations*. One can maintain the thesis that there is a relevant distinction between cognitive and social values (Lacey 2010, Chap. 11) — which does not mean that a given value couldn't appear, in different guises of manifestations, *both* in VC and in VS — being interpreted, in the former case, as a cognitive value, and in the latter case, re-signified as a social one.[2]

The class A in the value outlook is composed of *affinity relations* (either positive or negative) of the form a (V_i, V_j, σ_{ij}) that hold between any two values V_i and V_j (both in VC and in VS). The affinity strength σ_{ij} is a measure of the degree to which the manifestation of a value V_i encourages or hinders the manifestation of another value V_j. Thus, in our account the affinity relations express to what degree the fulfillment of a given value fosters or hinders the fulfillment of another particular value.

One should be aware that the values within a value outlook or a research strategy have themselves an internal dynamic of their own; as a result, the values evolve over time. As far as *cognitive* values are concerned, Larry Laudan (1984) has advanced the first ideas as to how they interact, on the one hand, with theories and methodologies, and has given, on the other hand, some hints about how they interact with one another. We are developing a general framework for analyzing scientific values, compatible both with SMT and the MI-SV model (enriched with some Laudanian insights). Our aim is to understand issues such as: how to include values in SMT in an organic way; how are value outlooks constituted; the questions of coherence within an axiology, axiological holism, axiological pluralism — we'll return to them later.

5. The kinematics of values (with some hints of dynamics)

The structure **V** — the value outlook — is of particular interest for the investigation of the dynamics of values in science; however, it harbors considerable complexity within it, to which we shall now turn.

First, we must acknowledge that any value[3] V exists in two dimensions, one objective and the other subjective. The former is the one composed of the objective characteristics or properties that the subject

[1] About the history of the value of control of Nature, see Mariconda (2006).
[2] A case in point would be, for instance, materialism in the 18th Century.
[3] Not to be confused with V "sans serif", which refers to a value outlook.

recognizes in the "value object" O. For instance, in the case of a painting, one could focus on the distribution of light and dark, the color palette, the type of stroke, the underlying texture of the physical support, geometric proportions within figures, vanishing points, linear dimensions, etc. Another matter is the assignment of the property (the 'value') V to a greater or lesser extent to object O by the subject S,[4] due *in part* (but not exclusively) to these objective properties.

This process is iterated over and over again, with an input based on various objects O_k (to which new ones may be added), leading eventually to a certain structure of values **V** (or value outlook) held by S, with different relative weights γ_i. This is, then, a first approximation to the process of development of an individual's value profile:

$$\mathbf{V} = \{\gamma_1(V_{1S}), \gamma_2(V_{2S}), \gamma_3(V_{3S}), \ldots, \gamma_N(V_{NS})\}.$$

(At this point, it is still not essential for our purposes to consider the distinction between cognitive values VC and social values VS.) Now, we can extend the value profile from the individual to the collective. The subject S (call it S_1 from now on), obviously, does not live in isolation, and will inevitably interact and exchange information with other subjects S_j — each having her own history of interactions with objects. As a result, each one from M subjects ends up developing her own particular value structure:

$$\mathbf{V}_1 = \gamma_{11}(V_1)_{S1}, \gamma_{21}(V_2)_{S1}, \gamma_{31}(V_3)_{S1},\ldots, \gamma_{i1}(V_i)_{S1},\ldots, \gamma_{N1}(V_N)_{S1}$$

$$\mathbf{V}_2 = \gamma_{12}(V_1)_{S2}, \gamma_{22}(V_2)_{S2}, \gamma_{32}(V_3)_{S2},\ldots, \gamma_{i2}(V_i)_{S2},\ldots, \gamma_{N2}(V_N)_{S2}$$

…

$$\mathbf{V}_j = \gamma_{1j}(V_1)_{Sj}, \gamma_{2j}(V_2)_{Sj}, \gamma_{3j}(V_3)_{Sj},\ldots, \gamma_{ij}(V_i)_{Sj},\ldots, \gamma_{Nj}(V_N)_{Sj}$$

…

$$\mathbf{V}_M = \gamma_{1M}(V_1)_{SM}, \gamma_{2M}(V_2)_{SM}, \gamma_{3M}(V_3)_{SM},\ldots, \gamma_{iM}(V_i)_{SM},\ldots, \gamma_{NM}(V_N)_{SM}$$

where M is the number of subjects, N is the number of values, $1 < i < N$, $1 < j < M$, and where γ_{ij} denotes the weight assigned to the value V_i by the subject S_j.

For simplicity, we are assuming all subjects S_i share the same list of values, but this does not need to be the case: there may be values that are present in the axiological structure of S_i but are absent from that of S_{i+1}. In this case, the values that are absent could be trivially absorbed into the representation by assigning them weight equal to zero.

Now, as a result of the interactions of the subject S_i with each other and with the objects O_k, the weights of the values in the individual structures $\mathbf{V}_j$ can readjust over time, assuming revised values γ' at the instant t':

$$\mathbf{V}'_1 = \gamma'_{11}(V_1)_{S1}, \gamma'_{21}(V_2)_{S1}, \gamma'_{31}(V_3)_{S1},\ldots, \gamma'_{i1}(V_i)_{S1},\ldots, \gamma'_{N1}(V_N)_{S1}$$

$$\mathbf{V}'_2 = \gamma'_{12}(V_1)_{S2}, \gamma'_{22}(V_2)_{S2}, \gamma'_{32}(V_3)_{S2},\ldots, \gamma'_{i2}(V_i)_{S2},\ldots, \gamma'_{N2}(V_N)_{S2}$$

…

$$\mathbf{V}'_j = \gamma'_{1j}(V_1)_{Sj}, \gamma'_{2j}(V_2)_{Sj}, \gamma'_{3j}(V_3)_{Sj},\ldots, \gamma'_{ij}(V_i)_{Sj},\ldots, \gamma'_{Nj}(V_N)_{Sj}$$

…

$$\mathbf{V}'_M = \gamma'_{1M}(V_1)_{SM}, \gamma'_{2M}(V_2)_{SM}, \gamma'_{3M}(V_3)_{SM},\ldots, \gamma'_{iM}(V_i)_{SM},\ldots, \gamma'_{NM}(V_N)_{SM}$$

[4] To be distinguished from the S "sans serif", which denotes a strategy of restriction and selection.

And so on, going through successive iterations at instants t'', t''',..., etc, generating weights γ'', γ''', ..., etc. The weights may be represented as an M × N matrix.

It is conceivable that (modulo some residual degree of individual variability) the process might converge and stabilize over time, approaching a kind of 'collective value outlook' for a certain community C, an axiology expressing *shared* values:

$$\mathbf{V}_C = \gamma'_{1C}(V_1)_C, \gamma'_{2C}(V_2)_C, \gamma'_{3C}(V_3)_C,..., \gamma'_{iC}(V_i)_C,..., \gamma'_{NC}(V_N)_C \quad (1)$$

Of course, this represents a global, collective value outlook — something like an "average" value outlook. $\mathbf{V}_C$ results from intersubjective interaction over the value matrix throughout successive iterations. The case where the axiology does *not* converge to a unique $\mathbf{V}_C$ would correspond, presumably, to scientific "crises" where there is widespread ambiguity and controversy as to what value outlook should be held by the community.

There are also the *individual* "final" value outlooks of the individuals j:

$$\mathbf{V}_j = \gamma_{1j}(V_1)_{Sj}, \gamma_{2j}(V_2)_{Sj}, \gamma_{3j}(V_3)_{Sj}, ..., \gamma_{ij}(V_i)_{Sj}, ..., \gamma_{Nj}(V_N)_{Sj}$$

There is a *reciprocal conditioning* between the collective level and the individual level, as far as values are concerned (as was already famously pointed out by Kuhn 1977). There may certainly be individual deviations from the collective value outlook, but in practice this situation may hold just up to a point only, particularly in science. If deviations from the "mean" value profile become or remain very large, two paths are possible: either the scientist tends to be excluded from the scientific community (a frequent outcome) or, in certain cases, she may trigger a value controversy that propagates throughout the community. Allegiance to certain structure of values is, we suggest, one of the main elements responsible for pertinence to a certain community, at least on a par with holding the same theories, concepts or "paradigms".[5]

Given the (evolving) value outlooks, both collective and individual, the interactions of the subjects with various objects of value O_k will generate over time a sequence of *value assignments* or *evaluations* α of said k objects with respect to values V_i with weights $\gamma^{(t)}$ at the instants t:

$$\{\alpha^{(t)}{}_{1j}\,(\gamma^{(t)}{}_{1j}\,(V_1)_{Sj})\,(O_k),\ \alpha^{(t)}{}_{2j}\,(\gamma^{(t)}{}_{2j}\,(V_2)_{Sj})\,(O_k),\ \alpha^{(t)}{}_{3j}\,(\gamma^{(t)}{}_{3j}\,(V_3)_{Sj})\,(O_k),\ ...,\ \alpha^{(t)}{}_{ij}\,(\gamma^{(t)}{}_{ij}\,(V_i)_{Sj})\,(O_k),\ ...,\ \alpha^{(t)}{}_{Nj}\,(\gamma^{(t)}{}_{Nj}\,(V_N)_{Sj})\,(O_k)\}.$$

Evaluations may evolve in time, and the relative weights of values might themselves vary over time within a value outlook as well.

Finally, we can talk of an *evaluation* or *appraisal* $\alpha(t)$ of a given theory **T** at instant t according to the values in **V** as a function

$$\frac{(\quad)\qquad(\quad)}{(\quad)\qquad\qquad\qquad\qquad(\quad)} \quad (2)$$

Such appraisals would then, within the scope of our model, guide theory preferences and theory choices in scientific activity.

[5] Further complications might be inserted into the picture, arising e.g. from various possible "nonlinearities" in the intersubjective interaction. For example, we could take into account the fact that different subjects within the community might attribute differential weights (i.e. higher or lower importance) to the judgements of certain persons — analogous to what Lehrer and Wagner point out in the case of rational consensus (1981, pp. 19-20).

It might be asked whether it does make sense to attribute numerical weights and compute a numerical value for theory appraisal. Do human scientific agents really compute numerical values for epistemic parameters with a view to their application in settling methodological matters? To this we might answer in the following way. To begin with, issues related to entrenchment and priority of values, fulfillment of values, and appraisal/evaluation according to values are matters of *degree*; it is plausible, therefore, to choose a kind of formalization in which numerical parameters could be computed and distributed along scales or rankings. Furthermore, one could consider our approach as an idealization, and, within the scope of this idealization, attribution of numerical values to parameters (i.e. understanding valuations not only as a topological, classificatory concept but also as a metrical, quantitative one) might be plausible and useful. Second, one could point out that this is but a first approach to the matter; so, in a later version of the model, a different type of parameter — for example, one of a discrete or a denumerable sort — might later be used, instead of a continuous real one; in this case, only orderings of weights and/or evaluations would be captured, instead of exact values. Finally, there is another reason for considering numerical parameters in our model: it allows a greater *controllability* of the statements formulated using the model, when confronted with specific historical case studies, as envisaged by Moulines (2014, p. 1506) in a different context. So, we can say that what is at stake here is not just formal rigour for its own sake — there are metaphilosophical reasons for pursuing it.

6. Values, methodology, holism and pluralism

We suggest that the quest for value-fulfillment is the causally effective factor behind theoretical restriction and empirical selection (and, one should add, theory choice as well). Note that, due to this role, both restrictive and selective at once, constraints $\mathfrak{T}$ and $\mathfrak{E}$ end up playing a role that is usually associated to the *methodological* apparatus of science. In scientific activity, methodological norms, criteria and rules attain a particular configuration, and act in certain ways, with a view to satisfy the posited values. A robust philosophical analysis of the connection between methodology, problems and values in science was developed by Larry Laudan and Kevin Kelly, in the context of the former's reticulational model of rationality, in which methodology is understood in terms of 'hypothetical imperatives' (Laudan 1984, 1987, Kelly 2000). Lacey also recognizes the existence of a tight connection between value outlooks and methodologies, so as to preclude the possibility of an "autonomous" methodology (Lacey 2010, p. 297).

It is worth noting that Lacey himself, despite his criticism directed towards the almost absolute prevalence of de-contextualizing strategies in modern and contemporary scientific activity, recognizes that this kind of strategy has some merits of its own and is fruitful from a certain point of view, and therefore should not be abandoned *simpliciter*. He suggests that scientists should strive to apply *strategy pluralism* — to employ a wider range of different research strategies in order to properly study and understand a certain domain (Lacey 2010, pp. 292-296, 2012).[6] However, a few points of criticism may be raised.

Three issues should be highlighted here. First, axiologies or value outlooks have a holistic nature. Second, piecewise modification of a value outlook is both a costly and a nontrivial issue. Third, pluralism of value outlooks and strategies is also a large-scale matter. Let's have a look at these epistemic

[6] His main example concerns the contrast between the strategy that supports high-performance, intensive, mechanized, monocultural and genetically-manipulating agriculture, on the one hand, and the strategy that grounds agroecology, on the other hand.

phenomena and their roots. This will improve our understanding of the structure and dynamics of value outlooks.

One could expect that a sequence of theories $\{\mathbf{T}_i\}$ developed, evaluated, accepted and applied according to certain restrictors $\mathfrak{T}_1$ (within a strategy $\mathbf{S}_1$) might show in the long run a certain degree of affinity with these very restrictors, due to the reciprocal conditioning that holds between both elements (which does not imply the nonexistence of transient maladjustments and tensions). For that reason, the successful "grafting" of a theory onto a strategy $\mathbf{S}_2$ different from strategy $\mathbf{S}_1$ within which it was originally developed is quite an unlikely possibility, for, eventually, clashes between theory and values are quite probable.

One must consider the *mutual reinforcement* (or *affinity*) *relations* and, conversely, the *inconsistency relations* between the values within a certain value perspective **V**. Some values will encourage the realization of certain others, while some values will discourage the realization of others. The mutually reinforcing relationships can be represented by positive constraints and mutual incompatibility by negative constraints. A positive constraint (resp. a negative one) $\sigma_{ik}(V_iV_k)$ indicates that the manifestation of the value V_i encourages to some degree (resp. discourages) also the manifestation of value V_k, or vice versa (for the sake of simplicity, let us take here the relationship posited by the constraints to be symmetrical): considering also the weights of values within the value outlook of a subject S_j, we have constraints of the form:

$$\boldsymbol{\sigma}_{ik}(\boldsymbol{\gamma}'_{ij}\,(V_i)_{Sj},\ \boldsymbol{\gamma}'_{kj}\,(V_k)_{Sj})).$$

The effect of this is that the axiology in a given strategy is endowed with a *holistic* character, and its bonds get more (or less) tight and cohesive. An axiology will be the more cohesive the more numerous the mutually reinforcing connections are therein, and the less cohesive the more numerous the relations of mutual weakening are. Thus, axiologies are far from mere disjointed sets of free-floating concomitant values. This entails, among other things, that the modification or revision in an axiology is not a trivial matter at all. Due to the distributed relations of affinity between values, pointwise modification of scientific axiologies is a delicate matter, and in any case seems to be a rather rare ocurrence, since it could quickly give rise to strong and quite involved internal axiological tensions. The replacement of a value by another could be costly — since the value that was abandoned might present strong reinforcement relations with other values, and the new substituting value might exhibit incompatibilities with the others. *A fortiori*, also the methodological changes are not trivial, since values and methodologies are coupled, as we have seen.

Given the texture of interconnectedness within a value outlook, and the fact that values operate collectively as a system, it is conceivable also that their meaning and their possibilities of interpretation are also, in some measure, contextual. For example, the value of empirical adequacy could acquire subtly different meanings according to whether we are looking at Galenic medicine or analytical mechanics or Lavoisierian chemistry or Boyle's experimental philosophy. Also, the value of materialism would receive quite different meanings in the hands of authors such as e.g. Priestley, Lavoisier, Descartes, Maupertuis, and La Mettrie.

Now, to take Lacey's most detailed case study, it would seem that, in order to develop a strategy that is *based* on the de-contextualized strategy, but *not* strongly based on the value of control over nature, one would end up with a completely new system, *even if all other values remain, at face value, the same* — because, without the value of control, the meanings and weights of the remaining values, their inter-relations, and the role played by them, would not be the same anymore. As a result of the points above,

therefore, genuine axiological / methodological pluralism may be a rarer occurrence than one might suppose at first, for it demands the parallel but independent development of whole large-scale strategies and value outlooks.

7. Conclusion

We have presented here a framework for the description and analysis of values in science. Our proposal is that value outlooks **V** can be viewed, first, as M × N weighted matrices representing sequences of individual value profiles or as N-vectors representing collectively shared value outlooks, and, finally, as a network of values interconnected positive and negative affinity relations (representing either mutual reinforcement or tension). Such value outlooks are best understood as components of structuralist theory-holons **H** as well as Laceyian research strategies **S**. Both structures belong to the level of *macrotheories*, i.e. structures that are usually of a wider scope and higher degree of historical stability and permanence than theories proper. This is to be expected, since values provide general constraints on epistemological and methodological processes in various registers that take epistemic units as their objects. In the case of theories, such processes include theory construction, theory appraisal, theory choice, and theory change; in the case of other epistemic units in science, we could mention model building, simulations, thought experiments, and so on. Since theories and experiments are the main epistemic units that are involved in the day-to-day theory-experience dialectics of scientific activity, they are the first to be modified, replaced or abandoned in case of tensions, disagreements or anomalies. There is a certain inertia as regards the propagation of the effects of such tensions and the consequences of decisions and choices across the other, increasingly more general and abstract meta-levels, such as the macrotheoretical, the axiological, the methodological or the worldview level. Thus, the dynamics of values and macrotheories usually exhibits a slower pace than the dynamics of theories — changes in value outlooks may take centuries, while changes in theories and experiments may take months or years (in some cases).

The present analysis could be viewed as but a part of a larger network-oriented philosophical image of science, in the following way: first, the evolution of value outlooks can be described, as we have seen, in terms of a matrix of values and a *network* of interactions (including particular value judgements, attribution of weights to values, affinity relations, appraisal of tensions between values, and re-evaluations of weights). This interaction, of course, does not happen in a vacuum, but over a substratum that is better understood as *another network* of interacting subjects that constitute the scientific community — the collective epistemic subject of scientific knowledge. This community, by its turn, builds, holds and applies certain large theoretical, conceptual structures that include epistemic units such as theory-nets and theory-holons — and ends up, in the course of time, constituting large-scale, densely interconnected *conceptual networks*. Finally, the community has certain cognitive attitudes about the epistemic units (or parts thereof) that include, for example, *beliefs* about laws and theories, as well as other kinds of attitudes such as holding, endorsing, pursuing and accepting scientific claims. Such beliefs and cognitive attitudes are also interconnected (e.g. by coherence relations, entailment/deductive connections, analogical relations, probabilistic relations and so on). So, we have at least four main different levels of networks in terms of which scientific knowledge is structured: a network of values, the network of scientific community taken as a collective, the theoretical/conceptual networks, and belief networks. We could say that in science "it is networks all the way down (and all the way up)". However, there is still a long way to go: contemporary epistemology and philosophy of

science are still struggling towards collecting pieces of a larger picture with a view to building a comprehensive philosophical image of science in terms of networks.

There clearly are still many pending tasks and open problems that lie ahead of our proposal. One task would be to investigate the conditions of convergence of the iterating individual value profiles towards a common shared value outlook. Under what conditions the individual value profiles can be said to converge smoothly? When, on the other hand, is there a possibility that a controversy about values remains stuck in an unresolved impasse? What mechanisms are brought to bear on the decision process in such troublesome cases? Further, what are some of the mechanisms whereby scientists cope with situations of tension between values? Another task is to search for a more refined formulation of the notion of value judgement. Related to the latter is the issue of describing and explicating the connection between value judgements (so formulated) and the spectrum of cognitive attitudes such as believing a theory, holding a theory, pursuing a theory, and so on. This is a question that is related to epistemic justification and has implications for a philosophical model of scientific rationality. Another open issue would be to investigate the relations that the distributed mutual affinities and tensions within a value outlook have with the notion of ideology (ideology could be viewed as related to the "entrenchment" of values and the holistic nature of a value outlook within a macrotheory).[7]

While an effort has been made in the above towards formulating a reasonably coherent and robust framework for describing values, the account, as it stands, is still in need of proving its worth. We believe that, as regards philosophical accounts of scientific knowledge in general, an important way of probing the approach would be to conduct historical case-studies. This way, we should be able to test its usefulness as a reconstruction tool, as well as appraise its potential to illuminate historical episodes (or its lack thereof).

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