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The Role of Philosophy of Science in Quantitative Linguistics

Original Study

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Abstract: The paper aims to evaluate the role of the philosophy of science in contemporary quanti-tative linguistics. The primary goal is the reflection of the scientific methods and models of scientific explanations (Köhler 1986, 2012) used in quantitative linguistics. The paper shows that the current philosophy of science has adopted some new approaches to ex-planation that are conducive to quantitative linguistics (Craver, Darden 2013, Eck, Mennes 2016). Above all, the philosophy of science offers new models of non-causal explanations (Reutlinger, Saatsi 2018; Lange 2017). The paper's primary goal is to propose a new topo-logical model of explanation in system-theoretical linguistics, following Kostić's (2019a) and Huneman's (2018) approaches. This model of ex-planation overcomes various difficul-ties of functional explanation, such as the nature of the structural axiom and the func-tional equivalents. Simultaneously, it establishes a non-causal form of linguistic explana-tion which builds on the previous analysis of quantitative linguists (Andres 2009; Ferrer-i-Cancho, Solé 2003; Hřebíček 2002).

Keywords: Philosophy of science, linguistic theory, system-theoretical linguistics, functional and topological explanation

INTRODUCTION

This paper was written by a philosopher interested in the theoretical structures built up by quantitative linguists in recent decades. The paper builds on the imperative that Gabriel Altmann brought to quantitative linguistics in particular—to based linguistics as an explanatory scientific discipline. As is well known, with this appeal Altmann distinguished himself against the qualitative linguistic approaches that focus only on the homogeneity level of linguistic investigation (see Altmann 1987, 227, 229–230).

Gabriel Altmann and Reinhard Köhler made an epistemological turn in linguistics—reconstructing the view of linguistics through the demands placed on scientific disciplines by the philosophy of science and thoroughly summarized by Mario Bunge (see Bunge 1983, 231–276; Bunge 1967a, 1967b). The normative demands of the philosophy of science—let us recall above all the deductive structure of theory, the D-N model of explanation, and the ability of prediction—were made by Altmann and Köhler as a natural part of linguistic theories (e.g., see Köhler, Altmann 1996).

The presented epistemological turn to explanations was possible thanks to the systematic preference of the empirical point of view—starting with specific linguistic data (concrete texts) in their greatest diversity and trying to create a real linguistic theory that can express some fundamental dependencies in the language system. While the qualitative approaches were too much tied to classifications and descriptions (whether in the case of linguistic structuralisms or generative linguistics), quantitative linguists were able to build theories that offered explanations based on scientific laws expressed by mathematical means (see, e.g., Köhler 1986; Köhler, Altmann 1996). In this respect, quantitative linguistics is the fulfillment of the ideals of the received view of the philosophy of science (see, e.g., Rosenberg 2005)—to replace vague concepts of social sciences and humanities with exact concepts, as in the case of the natural sciences (see, e.g., Rosenberg 2012).

The main topic of the paper is the nature of the scientific explanations provided by quantitative-linguistic theories. Both Altmann and Köhler model linguistic explanations by means created by Carl Gustav Hempel when using deductive-nomological (D-N) explanations (firstly Hempel, Oppenheim 1948) and especially one variant of it—functional explanation (Hempel 1965, 297–330). The D-N model of explanation conceives the scientific explanation as a specific kind of deductive inference between sentences in explanans and sentences in explanandum. A valid D-N explanation must fulfill four basic conditions, of which the central condition for us is the presence of scientific law in the explanans.[1]

The functional variant of the D-N explanation was built by Hempel as a kind of cybernetic alternative to the teleological explanation. It does not explain the behavior of the system teleologically, but as the fulfillment of a certain function of the system with respect to external conditions. However, Altmann's and Köhler's conception of functional explanation is not purely Hempelian; Bühler›s conception of a function is projected into it. Altmann expresses the connection to Bühler's (2011, 50–52) and Zipf's (1949) views (see Altmann 1987, 235; Altmann 1990).

A certain function can be fulfilled in various equivalent ways (these are functional equivalents). Deterministically, it is impossible to decide which of the equivalent ways of fulfilling the function will be realized. The principle of self-regulation (or, in the context of later synergetics, the principle of self-organization), which is given in the first position in the explanans of the functional explanation, can therefore not be conceived as a deterministic law (e.g., Hempel 1965, 319–325).

Precisely because of the absence of deterministic law in this variant of Hempel's D-N model of explanation, it is necessary to distinguish a functional explanation from a causal explanation. Because the functional explanation is not based on an unambiguous and always permanent connection between cause and effect.[2] It is not a matter of denying the existence of a complex network of causal relationships that results in a final state; a functional explanation does not need to reveal this complex causal network, it is based on the general principle of self-regulation (or self-organization) of (in this case) the linguistic system.[3]

The goal of this text is to place quantitative linguistics within the context of the contemporary philosophy of science. The main objective of the paper is to analyze current models of explanation, which have been described by philosophers of science in recent years and which can serve quantitative linguists as alternatives to functional explanation.[4] This goal is meaningful considering the emphasis that quantitative linguists place on the explanatory nature of linguistic theory (e.g., Altmann 1978, 1993; Köhler 1990) and the importance they attach to the philosophy of science (mainly Bunge 1983, 1967a, 1967b).[5]

I will try to show that several new models of explanation can be successfully used in quantitative linguistics. The first useful pair of explanation models are mechanistic (e.g., Craver, Darden 2013) and design (e.g., Eck, Mennes 2016) explanations. At least some subsystems of synergetic linguistics could be explained mechanistically (see below). Another group are models of non--causal explanations, the research of which, especially in the context of life sciences, is very popular in the current philosophy of science (e.g., Reutlinger, Saatsi 2018).

Where the previous alternatives are only outlined in the paper, the main benefit of the article is in the formulation of a model of topological explanation for system-theoretical linguistics. This model of non-causal explanation eliminates some problems of functional explanation (status of the principle of self-organization and functional equivalents). The starting point for its formulation is the models of topological explanation proposed by Huneman (2018, 2010) and Kostić (2019a, 2019b) in the context of life sciences.

BUILDING THE LINGUISTIC THEORY

Gabriel Altmann presented the base plan according to which the understanding of quantitative linguistics still occurs. Quantitative linguistics represents the real theory of language—Altmann presents it as a transition of linguistics into the new phase of exact scientific research (see, Altmann 1978, 2–4; Altmann 1973, 209–210). It was a kind of revolution (in the Kuhnian view) where even the subjective and institutional obstacles had to be overcome (Altmann 1973, 210–211). Linguistics starts

1 Other conditions include: the deductive nature of explanation, empirical testability, and the (approximate) truth of sentences in explanans and explanandum (Hempel 1965, 247–249).

2 However, in a broader context, Hempel states: "[…] the laws of self-regulation themselves are causal in the broad sense of asserting that for systems of a specified kind, any one of a class of different 'initial states' (any one of the permissible states of disturbance) will lead to the same kind of final state." (Hempel 1965, 326)

3 For the highly elaborated Theory of Inferred Causation see Pearl (2009, 41–64). The attempt to define a causal explanation in quantitative linguistics is present in Tuldava (1995).

4 Below I focus on selected approaches to explanation in contemporary philosophy of science; for a general current definition of the topic see Skow (2016).

5 They refer also to several texts from the received view of the philosophy of science e.g., Hempel, Oppenheim (1948), Nagel (1961), Hempel (1965), Popper (1972), and others. Most references to philosophical texts can be found in Köhler (1990), in addition, they also mention the texts of Nancy Cartwright, Paul Humphreys, Peter Railton, Wesley Salmon, and Bas van Fraassen.

to concern the dynamic aspects of language in contrary to the static approach present in generative linguistics (Altmann 1985, 181, 183–184).

It is an interesting thing which was not reflected in any anthology, that in a scientific research program of quantitative linguistics, we could see explicit fulfillment of normative claims of the first stage of the philosophy of science (Hempel 1965; Nagel 1961; Popper 1972). Precisely in these lines, Altmann describes what science is and how it is in the case of linguistics—Altmann is performing philosophy of science (e.g., Altmann 1993). When expressing what a scientific hypothesis is (Altmann 1993, 7), he—regarding Bunge (1967a, 229)—carefully distinguishes between guessing, inductive and deductive hypotheses, and laws in linguistics (Altmann 1993, 8). As a cornerstone, the linguistic laws are the most important, as "[…] statements about mechanisms which generate observable phenomena […]" and as "[…] statements that are well-founded both theoretically and empirically […]." (Altmann 1993, 8)

The summarization of the epistemological base plan for quantitative linguistics we can find in Altmann (1996). This plan offers two tightly connected paths: inductive, which accumulates empirical linguistic hypotheses, and deductive, which derives linguistic hypotheses from known axioms (Altmann 1996, 4–6). Altmann did not prefer any of the paths a priori; sometimes he was more optimistic about the inductive path due to the complexity of linguistic research (e.g., Altmann 1972, 6).

From the practical point of view, it is hard to clearly disconnect both strategies of linguistic theory building. Altmann is even writing about "an inductive-deductive theory" (Altmann 1993, 8).[6] Altmann is well aware of strict "data-fitting" problems,[7] but he believes in the collective power of scientific research (Altmann 1997, 18).

The inductive conception of the theory is provisional, Altmann (1996, 5) expresses the non-independence of the inductive method and the need to complete it with deductions from the theoretical assumptions.[8] The inductive conception is based on empirical generalizations and, in the case of quantitative linguistics, on heuristics that were successful in previous cases. Empirical generalization is not the same as a full-fledged theory. Altmann was well aware of this and expressed it several times in deductive conception of linguistic theory (e.g., Köhler, Altmann 1996; Wimmer, Altmann 2005).

The deductive path is primarily represented by Köhler's system-theoretical linguistics (or synergetic linguistics, e.g., Köhler 1986; Köhler 2012) and by the "unified approach" (e.g., Wimmer, Altmann 2005).[9] Köhler and Altmann (1996) commonly build the synergetic model of language even in its discrete and continuous approaches (Köhler, Altmann 1996, 65–72). They also elaborate here the functional explanation (in connection to Hempel 1965, see Köhler, Altmann 1996, 66), and they clearly interconnect it with Bühler's and Zipf's conceptions. They conclude that the synergetic model: "[…] gives the Bühlerian and Zipfian concept formation a mathematical foundation and thereby renders useful theory-building." (Köhler, Altmann 1996, 74)

Wimmer and Altmann directly state that the "unified approach" includes Köhler's system-theoretical approach.[10] In both cases, there is an axiomatized structure of the theory, a deductive-nomological model of explanation, and a hypothetical-deductive testing method. Both approaches are based on a structural axiom that characterizes language as a self-organizing system. Both approaches build on the functional form of the deductive-nomological model of explanation.[11]

Although I consider the relationship between the two approaches to be valid in this text, it is advisable not to consider them to be identical automatically. Wimmer's and Altmann's "unified approach"[12] is more focused on the systematic classification of different statistical distributions (for discrete and continuous approaches separately), which can be derived in a unified way from the initial linguistic assumptions (Wimmer, Altmann 2005, 792).[13] Köhler (1986, 2012), on the other

6 "An inductive-deductive theory is a system of hypotheses from which at least some are laws and many others are inductive hypotheses." (Altmann 1993, 8) I thank the anonymous reviewer who states that we should speak about an "abductive approach" in the case of quantitative linguistic theory-building.

7 He refers to Bunge as "a mere mathematical representation of a set of facts, even if true, does not explain anything" (Bunge 1983, 21; Altmann 1997, 18).

8 In the last two points describing the inductive approach, Altmann adds: "e) Put up the first empirical formulas that describe the course of the property or the relations well. […] f) Try to give theoretical reasons for these formulas, i.e., deduce them from theoretical assumptions." (Altmann 1996, 5)

9 Köhler uses the terms "unified approach" and "unified theory" when referring to Wimmer, Altmann (2005) (Köhler 2012, 22, 138).

10 Wimmer and Altmann state that the "unified approach" is: "[…] a logical extension of the 'synergetic' approach […]" (Wimmer, Altmann 2005, 792).

11 For a notion of functional analysis concerning the D-N model, see Hempel's "The Logic of Functional Analysis" (Hempel 1965, 297–330). Garson (2008) presents a modern evaluation of the concept of functional explanation.

12 However not the synergetic model present in Köhler, Altmann (1996).

13 Here are these assumptions for the continuous approach: "(i) Let be a continuous variable. The change of any linguistic variable, , is controlled directly by its actual size because every linguistic variable is finite and part of a self-regulating system, i.e. we can always use in modelling the relative rate of change . (ii) Every linguistic variable

hand, seeks to specify a structural axiom that establishes the possibility of deducing the theorems of linguistic theory; for him, specific statistical distributions are only a secondary manifestation of linguistic principles.

FUNCTIONAL EXPLANATION IN THE STREAM OF TIME

The functional explanation used in quantitative linguistics is based on Hempel's functional analysis (Hempel 1965, 297–330). The structure of the functional explanation in system-theoretical (synergetic) linguistics has been described many times, and we assume knowledge of its current form (see Altmann 1978, 5–7; Altmann 1981; Köhler 1986, 25–33; Köhler 1990, 13–16; Köhler 2005, 764–765; Köhler 2012, 174–177). Hempel's skepticism about the functional explanation remained beyond the attention of quantitative linguists. This skepticism is based on the difficulty of expressing the principle of self-regulation in the form of law (see Hempel 1965, 309, 326). These difficulties were not surmounted even by the subsequent (post-Hempel) analysis of this explanation model. It stands to reason that only the interpretation of the functional model of explanation, which interprets functional analysis as a kind of description, remains unproblematic (for a summary, see Garson 2008; for a more detailed analysis, see Benešová et al. 2018).

For Köhler and Altmann, the model of functional explanation makes sense as a counterpoint to structuralism, which, although it built linguistic theory by mathematical means, used these means only for the systemic description of language. But it also makes sense as a counterpoint to generative linguistics, which only builds models of formal explanation.[14] In addition, both Altmann and Köhler responded to Hempel's challenge and built a model of functional explanation on the structural axiom, which is understood as a required explanatory principle (for a critique of this assumption, see Meyer 2002; Zámečník 2014).

The key is the intention that as a system the language performs functions that meet the requirements of the environment in which the system is located. When examining a set of non-system requirements, behind the structural axiom a more diverse group of explanatory principles is found, and the common designation of them as economizing principles can be simplistic.[15] They define the full range of physical, cognitive, but also socio-cultural limitations of the speaker. Or rather, they approximate the breadth of these limitations. I believe that further specification of these requirements in a functional explanation (building models of other language subsystems) would lead quantitative linguistics into the arms of cognitive science and fusion with modern forms of generative linguistics (again, see Newmeyer 2016; Haspelmath 2004).

I consider a terminological change, the replacement of the term "need" with the term "requirement", to be an important moment in the development of the functional explanation model. It is a change of perspective because the original term ("need", *das Bedürfnis*) focused more on a self-organizing system as if it were an organism with needs. On the contrary, the term 'requirement' includes an external-system perspective, there are external-system requirements that the system must implement/fulfill. Thus, the residual of the teleological explanation disappears from the functional explanation,[16] and the functional explanation begins to approach the form of the functional explanation in cognitive linguistics (again, see Newmeyer 2016, 17, 22–24).

Despite the difficulties, a functional explanation seems indispensable, as no distinctive alternative has been identified. Nevertheless, I believe that it is possible to question its indispensability and, on the contrary, to provide new support to structuralist forms of explanation (for example, see Ferrer-i-Cancho, Solé 2003). It can be said that the path from "need" to "requirement" can be continued further to "constraints" (see below).

OTHER EXPLANATORY STRATEGIES IN QUANTITATIVE LINGUISTICS

Partly in connection with, and partly in parallel to, the introduction of the structural axiom as the main element of functional explanation, there have been several attempts among quantitative linguists to explain the main explanatory source of quantitative linguistics. In addition to Altmann's approach, discussed above, we consider Köhler's register hypothesis (Köhler 2012, 84–92) and Hřebíček's principle of compositeness (Hřebíček 2003, 1–8) to be the most important.

Köhler's hypothesis of the register is well known,[17] it is related to the effort to define the structural axiom

is linked with at least one other variable () which shapes the behaviour of and can be considered in the given case as independent. The independent variable influences the dependent variable also by its rate of change, , which itself, in turn, is controlled by different powers of its own values that are associated with different factors, 'forces' etc."

14 In the case of the modern "principles and parameters approach", see Chomsky (2015), however, the purely formal form of the explanation for generative linguistics no longer applies, cf. Haspelmath (2004). See also Newmeyer (2016), Egré (2015).

15 The requirements are hierarchized, which is clearly present in the syntax model, see Köhler (2012, 179, 201). Already in Köhler (1986, 151), we find the super-requirements the Stability and the Adaptation.

16 On the other hand, they remain, for example, in the term "enslaving" (Köhler 2012, 170).

17 Register hypothesis is a model of natural language processing. It postulates the existence of a register (e.g., a memory register) for language processing, which must store both components of language constructions (for

of system-theoretical linguistics. It is also related to Köhler's effort to define the basic system variable, *the Efficiency of Control* (*die Steuerungseffektivität*), and its regulating requirements, *the Stability* and *the Adaptation* (Köhler 1986, 150–151). For Köhler, Menzerath-Altmann's law (MAL) is a mathematical expression of the structure implied by the register hypothesis.[18]

In the register hypothesis, Köhler tries to remove the vagueness of the concept of the economization principle, which is generally expressed by Köhler in the concept of *the Efficiency of Control* (and two complementary requirements). The economization principle expresses the tendency of the system to adapt (as efficiently as possible) to external conditions, i.e., the ability to ensure the functioning of the system. The register hypothesis is intended to explain how this happens and to show that MAL is an expression of this tendency.

At the same time, we can understand Köhler's hypothesis of the register as a separate expression of the mathematical structure of language across its individual subsystems. The main feature of this structure is self-similarity expressed through MAL. Köhler's hypothesis would thus be tied more to a structural or even mathematical explanation, which is followed by the concepts of Hřebíček (and Andres).

Hřebíček, with support in the principle of compositeness, explains the presence of power-law among language plans (especially Hřebíček 2003, 1–8). Hřebíček expresses a zero variant of the register hypothesis, which does not bind to cognitive analogies (memory, workspace, etc.) as in Köhler, but works with the abstract mathematical structure of language. The principle of compositeness expresses the need for a composite arrangement of constructs from constituents and invokes the concept of pressure and such a force that increases with the increasing number of constructs in the constituent, which allows Hřebíček to derive power law (Hřebíček 2003, 8).

The notion of a register is assimilated here by the more general notion that a construct cannot be indefinitely large and has to be composed of parts (constituents).[19] This shows us, among other things, the transition from requirements to constraints. Hřebíček's explanatory principle no longer explicitly points to the scheme of a functional explanation, although it can be interpreted as an explication of the economization principle.[20] Hřebíček directly points to an analogy with physical principles.[21]

I believe that these approaches suffer, albeit for different reasons, from the same problem, which concerns the limited linguistic interpretation of the proposed explanation. For Köhler, the functional use of the register hypothesis is associated with the need to specify requirements by cognitive means. On the other hand, the principle of compositeness can hardly be described as a linguistic principle *per se.* The fractal structure of language, introduced by Hřebíček,[22] places the explanatory principle outside of linguistics itself—it is a mathematical explanation of the properties of the language system.

Therefore, I will now try to consider explanations in quantitative linguistics in the context of current debates in the philosophy of science and show that there are other models of explanation, which could be useful.

MECHANISTIC EXPLANATION AND DESIGN EXPLANATION

The current discussions on explanations in the philosophy of science[23] are characterized by a plurality of approaches, yet we can trace some interesting trends in them. The first of these trends follow a pragmatic turn that began in the 1980s when the model of explanation began to be understood as a means tied to a specific research strategy chosen by a particular researcher (e.g., Fraassen 2002; Cartwright 1999; Giere 1999). This pragmatic conception of explanation and, of course, also a scientific theory, is

each language level) and structural information about the connections of these components. The key is that this register is limited. The larger the number of components, the more structural information the register must hold. With the increase of structural information, the space for the components is reduced and they must therefore be shortened. For more comprehensive explication see Köhler (2012, 84–92). An alternative to Köhler's original hypothesis of the register was provided by Milička (2014).

18 MAL expresses the relationship between the size of a language construct and the size of the language constituent. To put it simply, the longer the language construct, the shorter its language constituents (see Menzerath 1954, 100). The derivation of this law and its precise formulation is given by Altmann (1980). Its mathematical formulation is: , where is the size of the construct, is the average size of the constituent and , and are parameters. MAL was also derived, for example, by Hřebíček (1994).

19 In essence, he changes the methodological maxim of Hjelmslev's principle of analysis to a theoretical principle.

20 By showing a path to the concepts of symmetry and invariance of language structure, he also copies the way in which the principles of economization have gradually abandoned classical physics—Hřebíček's interpretation is analogized by Newton's mechanics, see Hřebíček (2003, 7).

21 He ties linguistic considerations to the principles of symmetries used in physics, see Hřebíček (2002, 17–18).

22 Andres follows Hřebíček's conception of the fractal structure of language, which is demonstrated in the principle of compositeness (via self-similarity) and at the same time, Andres relies on a mathematical interpretation of de Saussure's structuralism, see Andres (2009).

23 I consider this discipline in its standard form, through its leading professional journals such as *The British Journal for the Philosophy of Science*, *Philosophy of Science*, or *Synthesis*.

most often found under the name "model-based view of theories" (mainly Giere 2006, 2004). In the spirit of this approach, we can interpret current discussions pointing to the dichotomy of mechanistic and design explanations.

In recent years, mechanistic explanations have undergone a great renaissance, specifically under the name "new mechanism" (see Craver, Darden 2013; Craver 2006). A scientist explains mechanistically in the case he manages to identify a (causally) connected chain of individual factors which are jointly responsible for the occurrence of a particular phenomenon or the realization of a specific state of affairs.[24] Although we can currently describe mechanistic explanations as mainstream, philosophers of science agree that it is sometimes more advantageous to explain phenomena through function or design, because the description of the mechanism is not known or does not seem adequate (see Eck, Mennes 2016). A scientist explains by design if he identifies the usefulness of some complex system designed to realize some state of affairs or allows a phenomenon to occur.[25]

At first glance, the current debate on scientific explanation may seem like a revival of the classical notions of mechanism and function. On closer inspection, we find that their novelty is mainly due to a change in perspective[26] — explanations are not examined as abstract operations, but as scientific research strategies (e.g., Piccinini, Shagrir 2014). If we adopt this philosophical view, it will not be a problem to identify both of these strategies in quantitative linguistics, sometimes isolated, sometimes connected. We will also be able to interpret system-theoretical linguistics in one way or another, and it will bring us liberation from the need to solve the technical difficulties of the explanatory model that we have been accustomed to accepting as a prescriptive tool of the philosophy of science. The view now focuses on the studied linguistic system "as if" a mechanistic process took place in it, or "as if" this system fulfilled a function.[27]

The graphical representation chosen by Köhler is a heuristic tool for the mechanistic interpretation of system-theoretical linguistics, at least where Köhler specifies causal dependencies between system variables (and requirements).[28] On the other hand, in cases where the relationship between system variables is stochastic, reference can be made to the design of a linguistic system that serves to implement functions in accordance with requirements. In this way, the classical Hempelian conception of functional explanation in quantitative linguistics can be reinterpreted in a new form of design explanation (see Eck, Mennes 2016).

However, seen in this way, the whole traditional effort of quantitative linguistics expressed in works by the recent proponents of the discipline is brought into question. The traditional normative demands placed by Bunge and Hempel on scientific theories are seen by this perspective as inadequate. Artificially created criteria cannot play a prescriptive role. The philosophy of science should rather humbly examine the plurality of scientific practices, because the explanatory strategy is defined for the scientist by his activity, not for the philosopher by his analysis.

I believe that this pragmatic approach, expressed in the modern form of the mechanistic and design strategy of seeking an explanation, may be not only acceptable but also inspiring for those quantitative linguists who prefer the inductive strategy of building linguistic theory (see Altmann 1996, 4–5). However, the current philosophy of science also offers the means for further building a deductive strategy (Altmann 1996, 5–6) to create linguistic theory. It shows how, while maintaining a prescriptive perspective, we can redefine the repertoire of explanation models and how we can find non-functional alternatives to causal explanations.

NON-CAUSAL EXPLANATION (RE)DISCOVERED

The emphasis on causality and a causal nexus in relation to explanation in the philosophy of science undergoes periodic oscillations.[29] In most cases, this oscillation has been triggered by the discovery of new arguments for the indispensability of causality concerning the validity of the explanatory model. In recent years, the situation

24 Glennan (2016, 799) defines the minimal mechanism as follows: "A mechanism for a phenomenon consists of entities (or parts) whose activities and interactions are organized so as to be responsible for the phenomenon." For a myriad of variants of mechanism expression, see https://plato.stanford.edu/entries/science-mechanisms/#RisNewMec

25 However, Craver's conception of the mechanism also aspires to explicate functional explanations, see Craver (2013) and Garson (2013). A similar strategy we can find also in Piccinini, Craver (2011).

26 Of course, the mechanistic explanation was indeed developed at all possible levels of conceptual analysis (including the relation to other explanations and the ability to accommodate them, including metaphysical conditions for defining the mechanism, etc.), see https://plato.stanford.edu/entries/science-mechanisms/#RisNewMec

27 In the philosophy of science, scientific models are sometimes considered in this respect as useful fiction, see Morrison (2015).

28 See Köhler (2012, 201), full lines should represent functional dependencies and dashed lines distribution dependencies.

29 In Hempel's original conception, causality itself had no place, it received attention in connection with the critique of the D-N model of explanation by Wesley Salmon. For a summary and details, see Salmon (1998).

has changed, again the importance of defining the causal nexus has come to the fore but in connection with the study of distinctive non-causal models of explanation (for a summary, see Reutlinger, Saatsi 2018).

Again, we could see this dichotomy of causal and non-causal explanation through the lens of traditional considerations (as in the case of the new mechanism) about causal law, which we already find in Hempel's Aspects.[30] However, this would again obscure the originality of the current considerations, which are based on the findings of cases of non-causal explanations in specific scientific strategies. This is not a mere armchair philosophy debate about the possibility of non-causal explanations. In this context, several non-causal explanations in physics (explanations through symmetries in fundamental physics, non-causal explanations in the case of critical phenomena), biology and life sciences (optimization, graph-theoretical approach, topological approach), ecology (critical phenomena, topological approach) and many others were studied (e.g., Lange 2017; Batterman 2011; Huneman 2010, 2018; Kostić 2019a, 2019b).

One type of non-causal explanation that receives much attention is a purely mathematical explanation of non-mathematical facts. The main advocate of this is Marc Lange (see Lange 2017), who documents them across the sciences (he understands symmetry explanations and some design explanations in life sciences in this way). I propose to examine the connection between these considerations of non-causal explanation and the purely structural explanation (e.g., French 2014), which we find in other authors, even in the context of linguistics (some variants of formal explanations). I believe that some of Köhler's, but especially Hřebíček's and Andres's ideas about the importance of mathematical structures in linguistics are very close to this type of non-causal explanation.

In connection with my effort to update considerations on explanation in quantitative linguistics, the aforementioned topological model of explanation seems promising. This is not a strictly mathematical explanation of non-mathematical facts, and at the same time, it is a model which has been successfully applied in life sciences for cases of systems that can be analogized to Köhler's system-theoretical approach.

The introduction of a topological model of explanation is found primarily in Huneman (2010, 2018). He is inspired by biological and ecological explanations concerning the complex interaction of proteins (protein networks) and organisms (ecological networks). The advantage and disadvantage of Huneman's approach is the consistent application of topological graph theory (Gross, Tucker 1987). The advantage is that it allows him to build, in detail, the relationship between the investigated system (biological or ecological) and topological space (the system is represented by topological space, and system representations of topological properties are sought, which are invariants of a certain type of topological space transformation; Huneman 2018, 117–118). The disadvantage is that he let himself be guided by the created topological representation of the investigated system without verifying the correctness of all necessary conditions for a valid model of explanation.

In this context, Daniel Kostić (2019a, 2019b) draws attention to the importance of two basic conditions: the asymmetric relation between the entities in the *explanans* and the *explanandum*,[31] and the condition for the support of the counterfactual. The validity of the condition that entities in explanans must support the counterfactual was not observed in Huneman's case. The condition of counterfactual support is a standard expression of the explanatory power of entities in *explanans* (e.g., laws) because it stipulates that if the conditions in *explanans* were not met, the corresponding effects expressed in the *explanandum* would not be present.[32]

I believe that by combining Huneman's version of the topological model of explanation based on topological graph theory and Kostić's conceptual analysis of a topological model of explanation that satisfies the conditions of asymmetry and support of counterfactual, I can create a suitable model of explanation for system-theoretical linguistics. This model may be an alternative to the currently prevalent functional explanation.[33]

NON-CAUSAL EXPLANATION APPLIED IN QUANTITATIVE LINGUISTICS

The application of a topological explanation to the case of Köhler's system-theoretical linguistics is a natural extension of the approaches already used (Huneman 2010, 2018; Kostić 2019a, 2019b) in a new context. By creating this model of explanation, I fulfill the ambitions of the contemporary philosophy of science, i.e., to apply philosophical concepts *in vivo*. At the same time, however, I also build on the prepared theoretical

30 Finally, precisely because of the lack of a causal explanation for cases of self-regulating systems, Hempel introduces functional analysis here, see Hempel (1965, 329–330).

31 This is a traditional condition that is often presented as the Flagpole Problem (see Bromberger 1966). It is a matter of ensuring that the explanatory power arises only from the premises of the *explanans* and not from the elements of the *explanandum*. Here I will not concern myself with this condition, respectively I will assume that it is met. For the sake of completeness, however, it should be noted that Kostić strives to satisfactorily meet this condition in his model of topological explanation (see Kostić 2019a).

32 In summary, scientific law (whether causal or non-causal) must support the counterfactual (see Lewis 1974).

33 At the same time, the problems the traditional functional explanation has will be eliminated—especially the problem of functional equivalents. But that is the subject of another text.

considerations in quantitative linguistics itself, which I presented above. The line of reflection of the functional explanation that led from "needs" to "requirements" can be extended to "constraints", which are studied in the context of the structural explanations of Hřebíček and Andres, and which lie at the core of the topological explanation.

In Hřebíček, in particular, I stated that rather than a functional explanation, it is an explanation based on the principle of compositeness. Also, in Andres's reflections on the fractal structure of the language, we find the means to build a non-functional model of explanation, in relation to the topological conception of fractals, which are used in the study of scale-free structures. In particular, this fractal approach makes it possible to capture the relations between parts of the linguistic system,[34] which is exactly where Köhler's idea of synergetic linguistics meets the possibilities of topological models. In line with Köhler's register hypothesis, through Hřebíček's principle of compositeness to Andres's linguistic fractal, I feel the gradual promotion of topological variants of linguistic explanation.

In my reasoning, I start from Kostić's and Huneman's conception of topological explanation, which I apply to Köhler's system-theoretical approach, based on a functional explanation. Kostić provides me with a model which fulfills the conditions for well-formed scientific explanations (especially the support of the counterfactual), and Huneman provides me with the means to transform functional Köhler premises into topological premises.

In the beginning, however, I must make a distinction, because Kostić proposes a model of topological explanation (i.e., the explanation that some A topologically explains B), with the condition of counterfactual support being met, in two modes. The vertical mode is based on the description of the global topology of the system, and the horizontal mode is based on the description of local topological properties (see Kostić 2019a, 3).[35] I base my formulation of the topological explanation in systems-theoretical linguistics on a horizontal mode because it works with the concept of local topological properties, which can be specified for a given linguistic subsystem. The vertical mode could only be applied for a complete system-theoretical approach, which is not yet available.[36]

I can now formulate a horizontal variant of the topological explanation scheme for system-theoretical linguistics. I will first present it schematically, and then I will comment on the individual premises:

EXPLANANS

1/ The linguistic system S, with the structure expressed by means of the relation among the elements of the system is represented by the model of the topological space P.

2/ *A* describes a set of local topological properties of the topological space P, *B* describes a set of local linguistic properties of the linguistics system S, and had the values of *A* been different, then the values of *B* would have been different.

//3// The set of local linguistic properties of the linguistic system S is represented by the set of local topological properties that specify its invariance regarding a class of transformations.

//4// For any class of transformations of the linguistic system S, the set of local topological properties defines the set of equivalence classes.

//5// Def. Equivalence classes are classes of manifolds that are equivalent regarding . (i.e., each of them being the transformation of another through a function that belongs to)/

EXPLANANDUM

B occurs. / The fact G (or *B*) is topologically explained by some subset from the set of local topological properties of the topological space P (or *A*).

Premise 1/ was created by modifying the fifth premise in the explanans of Köhler's functional explanation (Köhler 2012, 176), it is used because it expresses the structure of relations between the elements of the system, which enters the topological variant of explanation unchanged. Premise 2/ represents the use of Kostić's horizontal mode of topological explanation, which reflects the condition of counterfactual support (Kostić 2019a, 3). The *explanandum* in the simple form "B occurs" expresses the minimalist completion of the model of topological explanation

34 Caldarelli speaks directly about fractals in the topology (see Caldarelli 2007, 62).

35 For clarity, let us give Kostić's formulation directly: "(Vertical mode): A describes a global topology of the network, B describes some general physical property, and had A had not obtained, then B would not have obtained either; or (Horizontal mode): A describes a set of local topological properties, B describes a set of local physical properties, and had the values of A been different, then the values of B would have been different." (Kostić 2019a, 3) It is also worth adding that I exclude only the central part of Kostić's model, I do not focus on two other important premises: Facticity and Explanatory Perspectivism (Kostić 2019a, 2), which I consider valid.

36 A certain framework for the Vertical mode is present in Köhler's idea of *the Efficiency of Control*, which is determined by two requirements (*the Stability* and *the Adaptation*). An interesting line of inquiry is the application of Vertical Mode to the "unified approach" of Wimmer and Altmann.

for system-theoretical linguistics, which builds on the first two premises. In this minimalist model, the concrete means of the topological model are not specified (they are expressed only in the premises 3/–5/), and thus it is also not clear how the means of functional explanation of system-theoretical linguistics were transformed into a topological form. However, even though the minimalist model is complete, it includes sufficient conditions for the formulation of a topological model of explanation.

Premises 3/–5/ express concrete topological means used to represent the linguistic system (they are modified according to Huneman, see Huneman 2018, 117–119). Premise 3/ refers to local topological properties that define invariants of transformations of the topological system (and thus also invariants of transformations of the linguistic system). Local topological properties therefore represent Köhler's requirements. Transformations of the system, manifested by changes in linguistic quantities, are expressed regarding individual local topological properties through equivalence classes (premise 4/). These equivalence classes represent the topological expression of the original functional equivalents. Premise 5/ is the definition of equivalence classes.

Compared to the functional explanation model, the topological explanation is independent of the structural axiom (Köhler's first premise 2012, 176). The second premise of the functional explanation: "The requirements have to be met by the system." (Köhler 2012, 176) is transformed into a topological form, through local topological properties, which are understood as constraints of the system. Köhler's third and fourth premises, specifying functional equivalents and relations between functional equivalents, are transformed through the concept of equivalence classes.

I believe that the benefit of topological explanation over functional explanation lies in removing the structural axiom, which refers to the principle of self-organization of the linguistic system. Another advantage is the disappearance of the problem with functional equivalents—all equivalent possibilities for the conservation of the invariants of the transformations (local topological properties) are included in the equivalence classes, which are determined by the topological model itself. Thus, there is no uncertainty due to the unclear content of the set of functional equivalents in the functional explanation.

An interesting question is whether it would be possible to integrate individual horizontal variants of topological explanation in system-theoretical linguistics into one vertical mode of topological explanation. I believe that this approach could be an interesting challenge for the unified approach in quantitative linguistics. Again, as I have already stated, partial parts of such a model have already been proposed in the register hypothesis (Köhler and Milička), in Hřebíček's principle of compositeness and Andres's conception of the fractal structure of language. My conceptual analysis only provides a framework that can help unify these partial contributions.

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