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Author:

Gerhard Schurz

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NORMIC LAWS AS SYSTEM LAWS: Foundations of Nonmonotonic reasoning

Gerhard Schurz, University of Salzburg

1. Introduction: In Search for Objective Foundations

Since its beginnings (e.g., Reiter 1980), nonmonotonic and default reasoning was motivated mainly in a *subjective-epistemic* way. From our knowledge that Tweety is a bird *plus* the epistemic fact that we know nothing *else* about Tweety we conclude that Tweety is a *normal* or *prototypical* bird, and thus, that Tweety can fly. This approach was made explicit in *autoepistemic* logic (Moore 1985, Konolige 1994). But *how*, and *why*, can such a reasoning from *non-knowledge* to *knowledge* be *reliable*? Assume you try to read a book while driving a car. It would be a bad device for you to infer from your ignorance that the street is normal and thus straight, or that the traffic lights are normal and thus on green. What is the objective criterion which can tell us in which situations default reasoning has intended rather than catastrophic consequences?

Since its beginnings the main application domain of nonmonotonic reasoning were claims of normality or prototypicality, like *bird normally can fly*, or *the light normally goes on when the switch is turned on.* I call them *normic laws* and use to formalize them as $A \Rightarrow B$, where A and B are open formulas. The name goes back to Scriven (1959), who together with Dray (1957) has detected them in the debate on explanation in humanities and social sciences. The phrase "normally" seems to imply at least something objective - a vague statistical *majority*- or *most*-claim. However, even this statistical implication was doubted by several researchers, computer logicians (e.g., McCarthy 1986, Reiter 1987) as well as philosophers of science (e.g. Neander 1991, Wachbroit 1994). The problem is that, typically, we do not know statistical frequencies like *x% of all birds* (when?, where?) *can fly*, or *x% of all light switches* (when?, where?) *are functioning properly*. Hempel (1988) has argued that such frequencies are subject to indefinitely many *theoretically heterogeneous* disturbing factors, so that no theory informs us about frequency estimations of this sort. This has the practical consequence that such frequencies will strongly vary with *contingent circumstances*. Hence *random sampling procedures* concerning arbitrary "birds" or "light switches" will not be very useful.

But this does not imply that ideal (i.e., prototypical) normality is not at all connected with statistical normality, as argued by McCarthy and Reiter, but is just a practically useful *convention of speech*. In contrast, nonmonotonic reasoning can only be practically reliable, can only have a high predictive success rate, if statistical normality is at least a *necessary condition* of ideal normality. This thesis will be defended in this paper.

The need of such a relation between ideal and statistical normality for practically reliable nonmonotonic reasoning has been frequently pointed out by defenders of probability-accounts, as Adams (1975), Pearl (1988), and including myself. A technically demanding question is how to establish this relation in a situation where we are largely ignorant about the real statistical distributions. A well-known approach is Adams' and Pearl's *infinitesimal probability semantics*. Another approach elaborated in my own technical papers is *noninfinitesimal probability semantics*, where one assigns lower conditional probability bounds to normic laws and controls how these bounds are propagated and diminished when we draw default inferences (Schurz 1997, 1998).

This paper, however, is mainly nontechnical. It tries to answer a more fundamental question, namely: is there any *objective reason* for the relation between ideal and statistical normality, and if so, what is it? It has been shown by several authors that normic laws seem to be *omnipresent* in everyday life, in the 'higher' or 'life' sciences as well as in technology; so-called *ceteris-paribus* laws are often nothing but normic laws (Hempel 1988, Fodor 1992, Schurz 1995, Silverberg 1996). Is this merely a result of our *subjective framing* of the world which in fact is too complex to be understandable, hence a result of wishful thinking?[1] Or is there a deeper objective reason

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[1] *Inductive overconfidence* in a well-known phenomenon in cognitive psychology.

for it? In philosophy of science one usually distinguishes between *genuine laws* and merely *accidental regularities* by the fact that the former ones have a unified explanation by general theories, e.g. of physics (the so-called Ramsey-Lewis account; cf. Earman 1986). Is such an objective theoretical foundation possible also for normic laws?

In this paper I will try to give such a foundation. It will be based on *cybernetics*, *system theory*, and *evolution theory*. This foundation does not only explain why normic laws are omnipresent in practical life, life science and technology, but also why and how they are related to high statistical probabilities, and finally why we are usually unable to determine the exact numerical values of their statistics. This foundation, if correct, will at the same time point to a *wide range of applications* of nonmonotonic reasoning. For it shows that in all these domains, nonmonotonic logic is just the right sort of reasoning. Finally, such sort of foundation does not at all imply that the *subjective-epistemic* accounts to nonmonotonic reasoning are incorrect or inadequate. In contrast, it can explain *why* they are indeed adequate in a wide range of application domains.

2. Normic Laws as System Laws

An important distinction is the distinction between *natural laws* (laws of nature) and *system laws*.[2] Natural laws are the laws of physics. They hold in the universe as a whole. System laws describe the behavior of so-called *open systems*, which are abstractly modeled by cybernetics, system theory and evolution theory. They come in two kinds: *natural* or 'living' systems, the objects of biology, psychology, sociology, history and humanities, and *artificial* or technical systems, the objects of technology. Abstractly, both kinds of systems share the following features (Si for system theory, Ci for cybernetics):[3]

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2 To my knowledge this distinction was first introduced by my father J. Schurz (1990).

3 Cybernetics has been founded by Ashby (1964), system theory by Bertalanffy

S1) Open systems are physical ensembles composed of parts, placed into a (physical) environment significantly larger than themselves. There is continuous exchange of energy and matter between system and environment. The environment has resources to satisfy the system's 'needs' (see C1) but also to 'destroy' the system (see S2).

S2) In spite of S1, open systems preserve a relative strict identity through time - their state is called a *dissipative state* in systems theory (a stationary disequilibrium, far away from the thermodynamical equilibrium of closed, 'dead', systems).

C1) Their identity in time is abstractly governed by certain *ideal states* (or norm states, in German "Sollwerte")[4] which the system constantly tries to approximate by its *real states*. It does this by certain *organs* = *subsystems* which perform certain *functions* = *homeostatic regulatory mechanisms*.

C2) These regulatory mechanisms *compensate disturbing influences* of the environment. If such influences cause the system's real state to move apart from its ideal state, the regulatory mechanism initiate counteracting influences and keep them in force until the system has again reached its approximate ideal state. The compensation power of these regulatory mechanisms is limited; they work only if the external influences keep within a *manageable* range. Otherwise the system is usually destroyed (though sometimes it may be 'catapulted' into a new dissipative state).

This is an *abstract* description. *Why* are open systems omnipresent in our world? *How* have they evolved? This is different for natural and artificial systems. Natural 'living' systems have evolved in natural evolution, which is schematically described by *evolution theory* with help of mainly these assumptions:[5]

(1979), cf. also Stegmüller (1969, ch. viii), Mihajlo (1989), Nagel (1977).

4 This system-theoretic notion of an "ideal state" is different from the notion of "ideal state" used in physics. In physics, an ideal state is a counterfactual theoretical simplification assumption (cf. Rott 1991) which may be far away from the real state. In system theory, ideal states *must* be constantly approximated in order to survive. Cf. Wachbroit (1984, p. 587-9).

5 For evolution theory (founded by Darwin) cf. Kitcher (1985), Rydley (1993), Maynard-Smith/Szathmáry (1995).

E1) Natural systems come in larger populations. The individuals of a species have a finite life cycle; and there is a mechanism of (genetic) *reproduction*.

E2) There is a mechanism of 'blind' variation (through mutation and recombination) of species (= kinds of systems).

E3) The environment is competitive, it *selects* the fittest specii, i.e. those with highest reproduction rate. High reproduction rate is the ultimate ideal state of natural systems (individual fitness, healthiness etc., are derived ideal states).

E4) In order to exert selective force on species, the natural environment must be relatively stable (compared to the temporal rate of generation change).

Biological evolution is only *goal-directed* (cf. Nagel 1977), not *goal-intended*, since it is assumed that variation acts 'blindly', and is not the intentional result of some super-creator (God). In contrast, artificial systems are constructed by intentional (so far, human) beings. Their purpose, i.e. their ideal states, are defined by their creator. Hence artificial systems are *goal-intended* (with respect to the creator's goals). But since human creators are fallibel, also the evolution of technical systems shares important features with natural evolution (Bigelow/Pargeter 1987, p. 185). Systems which are properly functioning are eliminated and replaced by better ones; thus the creator takes over the role of the selector. There are two kinds of technical systems. *Non-automated* systems (e.g., cars) form only together with its (intelligent) user a self-regulatory system maintaining certain ideal states (purposes). *Automated* systems are self-regulatory by themselves (except for energy supply provided by the creator - at least so far). Finally, *cultural evolution* is a mixture of natural evolution and creation. The regulatory mechanisms of humans and social systems are of both non-intentional and intentional nature (in sociology one distinguishes since Merton 1957 between 'latent' and 'manifest' purposes).

This description of open systems explains why their behaviour obeys normic laws which imply high conditional statistical probabilities. Due to their regulatory mechanisms, open systems are normally in certain states and perform certain functional behaviour - their ideal or prototypical states or functions. Because of limited compensatory power, dysfunctions may occur, whence normic laws are subject to various *exceptions*. Yet it must be the case that open systems are in their ideal states in the high *statistical majority* of cases and times. For otherwise, they could not *survive* in evolution and would die out. Birds, for instance, can normally fly. Of course it is possible that due to an environmental catastrophe, all birds suddenly loose their ability to fly. But then (with high probability), the species of birds will become extinct after a short period of evolution. On similar reasons, human behave normally rational in the sense of egoistic purpose-orientation, and governments normally try to keep their countries economically intact; otherwise they will be overthrown or will loose the next elections. Analogously, electric installations normally work, for they are constructed in that way, and if this were not so, they could not survive in the economic market. Also in the technical domain, a small probability of dysfunctions is unavoidable. The dysfunction probability is here, at least partly, explainable and controllable by the involved risks and utilities, economic supplies and demands. For example, while the computers at plane stations used for boarding often have a breakdown, those in the plane used for flying almost never have one. Put into a nutshell, *prototypical normality and statistical normality are connected by the law of evolutionary selection*.

Thus system laws are normic laws. Generally, their behaviour is described by three kinds of normic laws:

1) *System-Organ-Laws:* Systems of species S_i have normally organs (sub-systems) of kind O_i. For example, birds normally have wings. Formally $S_ix \Rightarrow O_ix$.

2) *Organ-Function-Laws*: Organs O_i normally perform (or, are able to perform) function F_i. For example, animals with wings normally can fly. Formally $O_ix \Rightarrow F_ix$.

3) *System-Function-Laws:* Systems of species S_i normally perform (or, are able to perform) function F_i. For example, birds normally can fly. Formally $S_ix \Rightarrow F_ix$.

Laws of kind 3) are derivable from laws of kinds 1, 2 in the calculus of preferential entailment including negated conditionals (Delgrande 1988, Lehmann/Magidor 1992, Schurz 1998), if we make the weak assumption 4: $\neg(O_ix \Rightarrow \neg S_ix)$, i.e. it is not the case that animals with wings are birds only in the exceptional case. Then 2 and 4 imply 5: $S_ix \wedge O_ix \Rightarrow F_ix$ by *Rational Monotony*, and 5 and 1 imply 3 by *Cautious Cut*.

The functions F_i are realizations of the regulatory mechanisms which keep the system close to its ideal state, and the organs are the subsystems which perform these regulations. Of course, there exist *functional equivalents* (cf. Hempel 1959): the same regulatory mechanism (for instance, protection against the predator) can be realized by different functions (e.g., hiding, fleeing, self defence), and the same function (e.g., fleeing) can be realized by different organs (wings, long legs). System and evolution theory thus do not explain why this *particular* species has these particular organs with these particular functions. This is largely dependent on the contingent circumstances of evolution. If evolution takes place in another part of the universe, it will probably have produced species which are rather different than those on earth. In contrast, natural laws like the law of gravitation will hold there just in the same way as on our earth. Hence system laws are, unlike natural laws, not *physically necessary*, but involve a considerable *portion of contingency*.

Yet they also contain a considerable portion of physical necessity: if certain contingent conditions of evolution are known or hypothetically assumed, then evolution theory is able to predict the course of evolution. The quantitative models of evolution theory explain *why* normic laws describe the final result of a period of evolution. Assume, the genotype G of a certain phenotype P of a species S mutates into a variant G* producing phenotype P* which has a small selective advantage in the given constant environment. Then, completely *independent* from the initial statistical frequencies of G, P and G*, P*, the quantitative evolution models predict that after sufficiently many generations the population will be in an evolutionary equilibrium (not thermodynamically, but with respect to frequencies) where almost all S-members have phenotype P*, and even more have genotype G* (Rydley 1993, ch. 5). The reason why neither the P*- nor the G*-law is deterministic is simply that the systems are *open*, subject to external influences, which may cause organic dysfunctions (alterations of P*) or even genetic dysfunctions (alterations of G*). Similar hypothetical evolution models have been applied to cultural or technical evolution (Kitcher 1985). The *nomological*, i.e. *non-accidental*, character of normic laws is also demonstrated by the fact that they support *counterfactuals* (Nagel 1977, p. 273). For example, "if this bird (or this animal with wings) *would* be hunted by a predator, it *would* fly away". Or also: "if this unknown animal, hiding behind a bush, would have wings, then it could fly". On the other hand, "if this cow would have wings, it could fly" is wrong, since in the hypothetical situation (the revised belief set where cows have wings) the normic law that *cows have a heavy body structure* is *preserved* and implies that cows with wings cannot fly.

Since the detailed contingent circumstances of natural evolution are usually unknown, system and evolution theory do not provide a complete explanation of the normic laws describing the systems behaviour, but only an *explanation schema* (in the sense of Kitcher 1981). They explain only why open systems have *some* ideal states, and some organs with some functions performing the regulations necessary for survival; hence why open systems are described by some normic laws. But this is sufficient for our purpose - it is exactly the theoretical foundation we are after.

3. Ideal Normality Normally Implies Statistical Normality

In philosophy of science, some authors have doubted that *biological normality* in the ideal sense implies *statistical normality*. Both Neander (1991) and Wachbroit (1994) have argued as follows: it may always happen in evolution that, by an epidemy or catastrophe, an organ O of a species S becomes dysfunctional, hence it looses the function F for which it was selected. This argument gives me the opportunity to sharpen my thesis. Of course, catastrophes may happen in evolution. Normally the species will die out in such a case. It may also happen that a small fraction of the species changes its habitat and survives - which is one way how new species evolve. It may even be the case that the species which is extinguished by a catastrophe has existed just for a very short period of time, so that the prototypical function F of organ O had no chance to become the statistical majority among S-members. But the point is: these catastrophic situations of radical change can never become statistically dominant in evolution. For if they would become dominant, *evolution* *could not take place*. Note that I do not claim that continuing catastrophes are physically impossible, but only, that *given* that evolution had taken place, they are impossible. Evolution requires relatively stable environments (their temporal change rate must be some decimal powers smaller than the temporal change rate of generations). Otherwise environment cannot develop its selective power. On this reason, the connection between ideal normality and statistical normality will hold for *most* parts of evolution. It will *normally* hold. So, the connection between ideal and statistical normality in evolution is itself not deterministic, but normic.

Let me explicate the exact meaning of my claim that *ideal normality normally implies statistical normality*. Since I assume that normality always has a statistical *most*-meaning, this claim reduces to a numerically unspecified *iterative conditional probability assertion*. As soon as we allow predicates with more than one variable in our language, conditional probability assertions may be iterated (cf. Bacchus 1990, p. 91; Weydert 1997). For instance, we may say that most of the German cities are such that most of their inhabitants have a car. Formally $Gx \Rightarrow_x (Iyx \Rightarrow_y Cy)$; the variable subindices at the arrow indicate which variables get bound by the conditional most-quantifier. In probabilistic terms, $p_x(\ p_y(Cy/Iyx) = \text{high}) \ /\ Gx) = \text{high}$. In similar way, the normic connection between ideal and statistical normality is explicated by the following iterative normic conditional:

(C) For most species S and time intervals t of natural evolution it holds that if organ O of S-members contributes with function F to evolutionary fitness of S and was selected for that reason, then most members of S will have organ O in t, and most S-members having organ O will be able to perform function F.

A similar claim holds for the evolution of technical systems. Evolutionary fitness is replaced here by the given purpose of the creator, who also figures as the selector.

We finally give an explanation why we are typically theoretically *unable* and/or practically *unwilling* to specify the exact numerical probabilities corresponding to the normic system laws, although we know that they are high. *Theoretically* we are unable because these systems are open and thus described by *nonlinear* differential equations. If the strength of external influences reaches the dysfunctional region where the compensatory range of the system is exceeded - we call this the *critical range* - then the nonlinear dynamics becomes effective and *chaotic* behaviour results. This means that the point where a system starts to become dysfunctional will be extremely *sensitive* on *slight variations* of external influences (given they are in the critical range; cf. Schurz 1996). Thus, exact frequency numbers of dysfunctioning systems in critical situations are not *theoretically predictable*. This chaotic behaviour of systems in the critical range means practically that the frequency of dysfunctional systems will be strongly influenced by various heterogeneous environmental conditions. If we take random samples of dysfunctioning systems they will be completely *heterogeneous*. On this reason it makes practically not much sense to estimate the exact frequencies of normic laws by sampling procedures. Of course, it may well make sense to estimate them in *restricted* and defined situations. For example, biologists may be interested in the frequency of certain birds, e.g. pigeons, which are unable to fly in a certain geographic regions, in order to infer something about a certain disease. Or, engineers will be interested in the frequency of dysfunctioning refrigerators among refrigerators when coming out from their production plant, while what happens with them afterwards will depend on contingent circumstances of their household. This is also the reason why I have suggested that in noninfinitesimal probability semantics, the lower probability bounds of normic laws will depend on the application context and thus should be specified by the *user* of a nonmonotonic reasoning system instead of being predetermined by a system-in built threshold value (Schurz 1997).

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