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Metacybernetics: Towards a General Theory of Higher Order Cybernetics

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Abstract: Metacybernetics refers to the higher cybernetic orders that arise in living system agencies. Agencies are complex, and for them to be viable and hence survive, they require both stability and uncertainty reduction. Metacybernetics is defined through a metasystem hierarchy, and is mostly known through 1st and 2nd order cybernetics. In this exploratory paper the purpose is to create a framework that can underpin metacybernetics and explain the relationship between different cybernetic orders. The framework is built on agency theory which has both substructural and superstructural dimensions. Substructure has an interest in stability, is concerned with the generation of higher cybernetic orders, and is serviced by horizontal recursion. Superstructure is concerned with uncertainty reduction by uncovering hidden material or regulatory relationships, and is serviced by vertical recursion. Philosophical aspects to the framework are discussed, making distinction between global rationality through critical realism, and local rationality that relates to different cybernetic orders that correspond to bounding paradigms like positivism and constructivism.

Keywords: metacybernetics; metasystem hierarchy; cybernetic orders; living system stability; horizontal recursion; uncertainty reduction; vertical recursion; critical realism

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1. Introduction

Living systems are autonomous and complex, and exist in a state of bounded instability in which there is an ever-present dynamic balance between order and disorder at the edge of chaos [1]. In this condition, a system reaches the threshold of its control, patterns of behaviour continually and non-deterministically fluctuate, making it difficult to realise long-term goals, and small perturbations can be subject to large amplification, resulting in unpredictable complex behaviour representable by hidden patterns. Such patterns can be uncovered by delving deeper into the situation being investigated [2]. The interactions that occur in such living systems tend to be non-linear, experience random perturbation, may have parallel processes, and are coevolutionary with respect to the interactions between agents and the environment [3]. Living systems are open to their environment, interact with it, and have flows of information, energy and physical material with it. This very openness to interaction requires that they build an internalised (e.g., mental) model of reality that they adopt as its virtual representation that is then used to regulate their behaviour [4]. They are also self-organising, maintaining internal order that contributes to their viability, the latter ensuring their survival into the future through efficacious adaptation to changing environmental conditions. Their capacity to efficaciously adapt is described by Ashby's law of requisite variety [5,6], which responds to malevolent (productive of harm) environmental variety impacting the system. Responding to this variety, the law says that the system needs to find appropriate responses (requisite variety) which allow it to efficaciously adapt to that malevolence. Boisot and McKelvey [7] have proposed the law of requisite complexity which says that to be efficaciously adaptive, the internal complexity of a system must match the external complexity it is confronted by. This necessarily includes the internalised representation of environmental characteristics that may explain that malevolence, and which the system uses to determine its requisite variety.

Efficacious adaptation has two requirements: (1) a capacity for uncertainty reduction, which involves the discovery of hidden aspects of a complex situation which can then contribute to identifying the nature of the requisite variety; and (2) the maintenance of stability that ensures that the variety of responses is requisite, where the relationship between the external entities (i.e., objects) and their internalised representation (e.g., in a mental model) has relatable characteristics.

With respect to (1), for uncertainty reduction under complexity it is recognised that if for a given situation available information is inadequate, then there is a need to drill down deeper into its detail in order to obtain sufficient information to inform strategy and action. In an illustration of this, recognising Simon's [8] living systems notion of system hierarchy, Stafford Beer [9] developed his Viable System Model (VSM) intended to analyse and diagnose problem situations. In this he was concerned with viable systems, autonomous entities that have within them autonomous entities [10], recognising that every viable system has within it, and is contained within, a viable system [11], and from this principle he adopted a recursive technique that we shall here call vertical recursion. In this, his model could be applied at each of three sequentially connected levels of detail, each level being a depth of vertical focus (using the analogy of a microscope zooming down to collect more detail). These foci, he deduced, would provide sufficient information about hidden detail in the situation of interest to enable requisite variety strategies to arise, leading to action that would ensure viability. The decision on which foci to frame is dependent on the context. As an illustration, given a context of a competitive university environment and a need by a university to ensure viability, the top focus might be the university, the next focus down the faculty, and the third focus its relevant department(s).

With respect to (2), the stability referred to is sometimes said to be structural and hence a qualitative condition of the system. When perturbations from a system's environment impact on it, these will affect it in a way that is structure determined, so its response will be limited by the capabilities of the structure itself to respond. While perturbations may occur in expected ways, under complexity they may also be indeterminable and subject to chaos, a situation where the system is structurally unstable and highly sensitive to small random perturbations. Such tendency towards instability can also be explained in terms of the relationship between an external object and (through observation) its internalisation as an ideate (i.e., the internal image/model of the observed externality that makes the system anticipatory) and which will be used as a token to determine behaviour. Where the object and the ideate are sufficiently dissimilar, responses will be inappropriate. The creation of that ideate now becomes an interest. Consider that an object is a symbolic entity that participates in a network of interactions while simultaneously taking on an apparent solidity and stability from these interactions [12] (as an aside, it may be noted that since an interaction is a mutual or reciprocal influence that produces an effect, the term *effect* can be used as a broad term to include *object*). The said solidity occurs through a process of evolution, where the observed and the ideate may become sufficiently similar through a discrete dynamic process [13] that uses repeated observations [14] of the externality.

Stability and uncertainty reduction are independent of each other, but they are also related iteratively. This is because if an externality has been internalised (to produce an ideate), uncertainty reduction is able to improve the ideate progressively which, in turn, for all things being equal, will improve stability to some limit. When an externality and its internalised ideate are somehow deemed to be sufficiently close because further iterations have no determinable consequences for the structure of the ideate, then that limit will have been achieved. Within this construction, stability and uncertainty reduction can be taken as necessary and sufficient conditions for viability (e.g., [15]). These dual terms apply whenever dual properties are deemed to exist for a given entity, the necessary condition enabling that property to exist, and the sufficient condition providing essential support for that condition without which that which is necessary cannot be sustained.

Another way of describing the relationship between the externally observed object and its ideate is that they should be synergistic—so that the ideate representation has relatable "object" regularities. Therefore, if the system is stable, then the ideate as a representation of the object is used by the system to determine strategic action, and the object and its ideate should be sufficiently similar. For this to happen, the object must also be a reflection of system dynamics within which an observer and an observed object cannot be distinguished, and where they are together the result of some aspects of dynamic interaction between the system and its environment.

Living systems are metacybernetic in nature. The system itself is taken to be a relational conglomerate that exists as an ensemble of mutually interactive related parts (its subsystems), and from which patterns of (general) relationships can often be discerned. This perspective is embedded in the ideas of the Russian thinker Alexandr Bogdanov [16], who began writing in 1904 on his empiriomonistic ideas of the philosophy of cognition and being. It resulted (from publications really beginning in 1917) in his universal science of organization (called Tektology) which, according to Bello [17], is equivalent to Bertalanffy's [18] later general systems theory.

A conceptualisation associated with the living system is the metasystem, originating from the ideas of Gödel in 1931 and pragmatically adopted by Beer [19]. Envisaged as a virtual accompaniment to a physical system, the metasystem constitutes a framework that describes system functionality, and is a governing structure that enables subsystem coordination and integration under complexity that is otherwise inaccessible to individual constituent subsystems [20].

Cybernetics, as a companion to living system theory, arises with the conceptualisation of reflexivity, and as a process it is used to regenerate a system through a changed perspective that now becomes part of the system [21]. This occurs through various self-processes such as self-organisation, self-reference, self-production, self-creation and self-analysis. As will be seen, reflexivity is instrumental in identifying the general relationships that emerge to become part of the system's regulative structure.

The purpose of this paper is to create a basic framework that is able to explain the relationship between different cybernetic orders through which stability and uncertainty reduction can be explored. To achieve this, it will be explained that there is a need to introduce two types of recursion, horizontal and vertical. Both have a minimal entry with 1st order cybernetics, when horizontal recursion occurs in a system that can be represented through some virtual meso-regulatory [22] structure. In 1st order cybernetics, the virtual regulatory system is external to the living system, and through environmental stimulus it comes to exist as an abstracted systemic layer the origin of which derives from environmental behaviours and experiences, and this conditions a class of living system behaviours [23–25]. Thus, for instance, an association may be made virtually between a behaviour and a negative or positive consequence of that behaviour. As an illustration in of classical conditioning in psychology, Pavlov [23] demonstrated that he could condition dogs to involuntarily produce anticipatory salivation resulting from repetitive stimulus. Skinner [25] introduced instrumental conditioning that unlike Pavlov's experiments has voluntary attributes. Skinner's ideas derive from Thorndike's law of effect in which the effect of one's action (which is either satisfying or not to a subject) influences the likelihood of repeat behaviour. While the virtual system in Pavlov's mode represents 1st order cybernetics since it is purely structure determined, Skinner's is 2nd order cybernetics since satisfaction is a cognitive condition. In 2nd order cybernetics, virtuality is explicitly represented as an ontologically distinct metasystem that connects to the system.

Vertical recursion applies to 1st order systems when deeper states of reality are explored in order to uncover hidden relationships. Here, horizontal recursion will be used to explore 2nd and higher order cybernetics (this being related to Foerster's notions of stability), and vertical recursion will be set within the ideas of Stafford Beer's Viable System Model, and then extended to higher order cybernetic models.

Prior to this, however, we consider the nature of metacybernetics and how a system's regulatory structure emerges from its general relationships. This will be followed by consideration of the philosophical basis that underpins our framework. Now, philosophy is concerned with such attributes as reason, existence, knowledge and values. The rationale for considering it in relation to metacybernetics is that it provides argumentative scrutiny that can critically illuminate flawed reasoning by explicating hidden attributes that include perspective, images and symbols. It can also reveal relationships that can address potentials for obscurity or contradiction. Now, Lepskiy [26] considers the philosophy that relates to 1st, 2nd and 3rd order cybernetics in terms of "local" rationalities, but to create a potential that is able to elaborate on his approach, there is a need to also explore the global rationality into which these localities sit. This is explained by Mingers [27], who has argued that cybernetic principles are coherent with the philosophy of critical realism. Lepskiy's local rationalities are relationally tied to cybernetic orders, each of which constitutes a relational subject (that is constituted within critical realism). The relational subject is, for Donati ([28], p.352), an agent (as subject) that in relation to others is "a 'relational I' that not only acts and is involved as Self in these relations, but re-elaborates itself in/through/with these relations." As such, these re-elaborations can be represented in terms of higher order subjects (i.e., metasubject, metametasubject, . . .) relationships in metacybernetics.

2. The Nature of Cybernetics

There are many definitions of cybernetics [29], with illustration in Principia Cybernetica Web: the 18th century French physicist and mathematician André-Marie Ampère thought that there was a need for a science of control that could be used on governments; some two centuries later, in the 1940s, for Norbert Wiener it is the science of communication and control in the animal and the machine; Warren McCulloch thought it to be an experimental epistemology concerned with communication between observers and their environments; Stafford Beer considered it to be the science of effective organization; and Gregory Bateson saw it as form and pattern. This lack of consensus in even a definition indicates fragmentation in the science of control [30,31].

Given complex problems with issues that need to be resolved through intervention, metacybernetic modelling offers a clear promise to provide theory to pragmatically service needs. It offers a multidisciplinary field which, following Heylighen and Joslyn [32], has so far not really become established as an autonomous discipline. However, it lives well in various fields of study, for instance, as a branch of systems, and in the field of philosophy, as well as in other areas such as biology and environmental studies. Politics is another example, a field which is inherently multidisciplinary and has its subject history populated with systemists. Another field is psychology, and in the foreword to the Yolles and Fink [33] book on personality theory, Daniel Cervone has noted that it is through higher order cybernetics that insurmountable problems of the mind (including that of the nature of consciousness) might be resolved.

Cybernetics often uses such concepts as information, feedback, variety, viability, homeostasis and entropy, and its approach is wholistic. While sometimes represented as the science of communications and control [33,34], it can be more broadly seen as the study of the interrelationships between an assembly of interactive systems or their entities without regard to structure [35]. The rationale for this is that, in a living system, generalized relationships develop that can in due course emerge as its regulatory structure.

2.1. Orders of Metacybernetics

Cybernetics for Heinz von Foerster involves observing systems, a notion that came to be consistent with the philosophy of radical constructivism (which takes a pragmatic position on reality, truth, and human understanding), and which was a major shift from more traditional positivist thinking about cybernetics. As a result, a perspective arose that cybernetics could be distinguished locally into distinct orders each with their own rationality that conform to given local paradigms. Therefore, for instance, its 1st order conforms to the positivist paradigm, and 2nd order essentially conforms to the constructivist paradigm.

Foerster [36,37] was interested in developing what has been referred to as a metacybernetics, and we shall take this to embed the idea of distinct cybernetic orders. Consider for the moment *1*st and *2*nd order cybernetics. In *1*st order cybernetic systems, regulatory control is imposed from an externality. In contrast, in *2*nd and higher order cybernetics, regulation has a substantively internal derivation. Another aspect that distinguishes *1*st and *2*nd orders is that the former is mainly directed towards problems of control and homeostasis in physical and engineering contexts, while the latter also considers problems of growth and morphogenesis in biological, economic and socio-political systems [38].

Foerster became enthused by the work of Piaget and adopted his ideas to define 2nd order cybernetics. This resulted in a theoretical transformation in the field of regulatory control which linked to living systems theory through processes of self-organisation [39–42]. As part of this journey of theoretical advancement, Maturana and Varela [43] introduced the term autopoiesis, a network of processes that enable a living system to self-produce elements of itself required for tasks like self-organisation and adaptation. The nature of this network is that multiple agents undertake distinct processes that may occur in parallel simultaneously or across time and functional space in order to service task needs.

Stafford Beer was also a major influence in identifying the nature of *2*nd order cybernetics. For him, it involves a dual ontology involving a metasystem addended to a system, the two somehow connected with a network of processes called autopoiesis (self-production). It evolved with Eric Schwarz [44], for whom it was insufficient to consider only self-production. Taking ideas from people such as Ashby, Beer, Maturana, Prigogine and Jantsch in the 1970s and 1980s [45,46], he argued that in living systems the inadequacy of autopoiesis could be resolved by an additional network of learning processes called autogenesis (self-creation). This moved living systems into an ontological triad essentially involving a metametasystem, a metasystem and a system, all interconnected by autopoiesis and autogenesis, thereby creating a *3*rd order cybernetics. Like Schwarz [47], Lepskiy [26] has more recently been concerned with 3rd order cybernetics as living systems with a capacity for adaptation. His ideas have resulted in a useful definition of *3*rd order cybernetics, as adopted by Chaturvedi [48], that involves an active-interactive element in a circuit that enables it to redirect itself in order to adapt to its context.

The *1*st and *2*nd metacybernetic orders have been distinguished by Heylighen and Joslyn [32] in terms of the observer and the observed as:

- *1*st order cybernetics involves the study of a system as if it were a passive, objectively given "thing" that can be freely observed, manipulated, and taken apart.
- *2*nd order cybernetics is normally concerned with an organism or social system, and it recognises that the system is an agency in its own right, interacting with an addended observer; observers and the observed cannot be separated, and the result of observations is dependent on the interaction between them.

While the idea of the observer has been useful to explore *2*nd order cybernetics, it does not provide a sufficient generality in explaining the higher orders of metacybernetics. The family of higher cybernetic orders constituted as a metasystem hierarchy, while akin in concept to Simon's [8] notion of a system hierarchy, is rather concerned with ontological distinctions across metasystems that determine cybernetic order.

2.2. Metacybernetic Systems as Agencies

Here, we adopt the idea that (living) systems are agencies with a population of agents that are subject to its regulation. In adopting this view, there is an assertion that living systems are active participants in their own environment [49], if acting through their agents, rather than being passive abstract concepts. We shall also implicitly adopt the ideas of living system Agency Theory [50]. This is a general theory that has two dimensions: superstructure and substructure, where:

- Superstructure involves theory-building and it does this through the integration of commensurable configurations like culture and norms. Each configuration is also a schema—a structured knowledge framework that defines a pattern of thought or behaviour and set of relationships that represent effects [51]. They have propositions relating to their characteristics, relationships and entailments, though information about these may be incomplete under complexity.

- Substructure is defined through foundational causes expressed through the dual properties of causal-agents and causal mechanisms. For a substructure to exist, one can consider these attributes in terms of necessary and sufficient conditions. A necessary condition for a substructure is that there exists a causal mechanism—a process or pathway through which an outcome comes into being. A sufficient condition for a substructure is that there exists a causal-agent—a dynamic element that produces an effect or from which events result, and it has properties that explain outcomes and associations. As an example, a causal-agent may be taken as an attribute of *self*, which inherently involves feedback processes [52], and which is instrumental in creating processes such as self-organisation. Thus, *autopoiesis* (self-production) is a causal-agent with a property of ontological process transformation, so that external environmental effects are manifested in different parts of agency's internal environment through outcomes such as internalisation (resulting in ideate formation), learning and adaptation.

The relationship between them is given in Figure 1 (adapted from Yolles and Fink [33]).

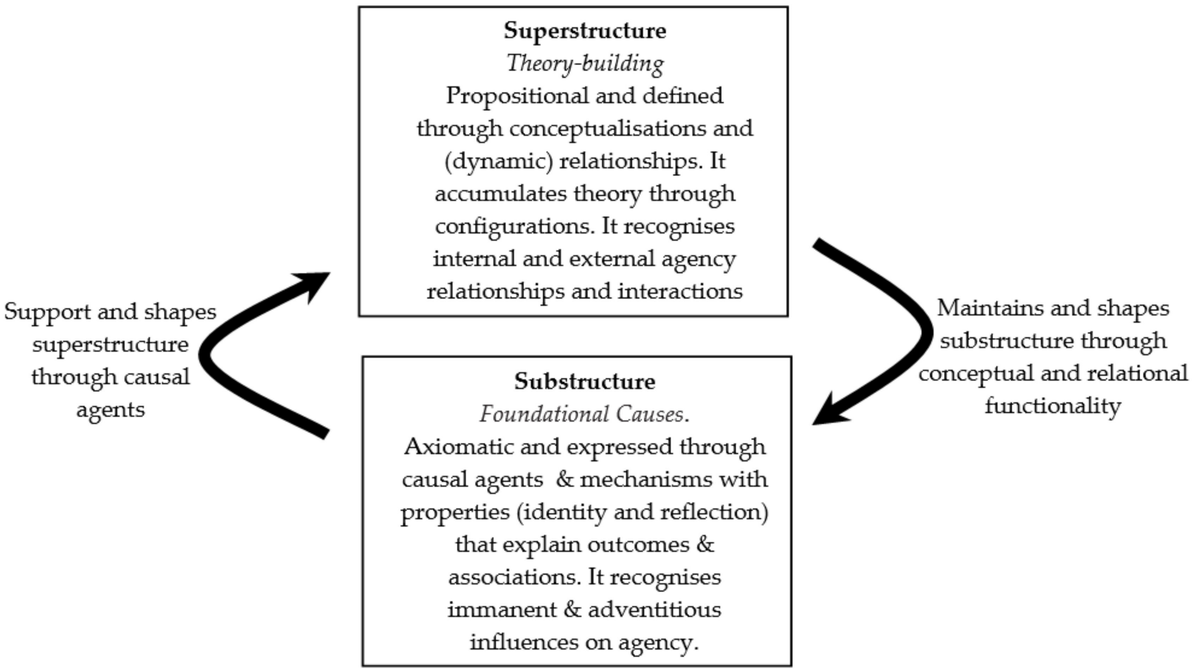

Figure 1. Nature of Agency as a General Theory with Reflexive Relationship between Substructure and Superstructure.

Causal mechanisms and causal-agents are important attributes of substructure since they determine and create foundational elements of a theory. Thus, in metacybernetics they explain the base function of feedback that occurs in each cybernetic order. That a particular order occurs requires that it has causal-agent functionality.

Now, a living agency is autonomous as is its population of living agents (as subjects), where the agents may themselves be living subagencies. There is a causal distinction between the agency (as the macro system under consideration), and the agent (as a micro subject of the system which may itself be a subsystem). Agency, as a living entity, involves action or intervention which produces a particular effect, this denoting *causation*. It acts though agents as its subjects (with a quality, attribute, or relation that may be affirmed or in which it may inhere) and takes an active role in producing a specified effect—this denoting *cause*. Thus, agents cause effects that precede, and are responsible for, effects that follow, while causation is the relationship that exists between cause and effect. In other words, agents create effects while agencies are caused to make effects. We note that we are here referring to micro agents that are agency subjects with behaviour that contributes to superstructural episodes, not to be confused with causal-agents that are part of macro agency substructural processes.

Both agencies and their agents are taken to be autonomous entities that interact with each other in a given domain and with respect to self-derived and perhaps determinable purposes. Agencies apply controls to their population of agents by regulating their options for interaction. These interactions occur as the direct effect that one agent has on another, and the nature of the effect is determined to some large degree by the relationship (connection, association, or involvement) between them. Where interactions result in general interactive relationships, regulatory processes may inherently develop that become generic, enabling the emergence of regulation. Determining relationships therefore facilitates regulatory processes.

One of the features of agency is that it is capable of internalising aspects of an external environment. This does not require that it is a conscious entity since the condition of living may involve many stages in the evolutionary process, including a primitive non-consciousness that still enables living systems to respond to environmental influences [53,54]. Internalisation occurs through the dual processes of assimilation and accommodation where:

- Assimilation occurs when an observed effect is brought into an agency as information through some inherent process of categorization and encoding. It enables the integration of any sort of reality into a virtual ideate structure, and learning is possible only when assimilation is active. It involves operational/organisational closure thus acquiring elements from the environment and integrating them into its own inner processes, while maintaining both its identity and its viability. It also establishes an anticipative schema as a structural potential by incorporating indicative effects from the environment to its pre-existing schemes of motor activity.
- Accommodation occurs where the said information becomes incorporated in an agency as an ideate, thereby modifying agency as part of an adaptive process. It creates an anticipative structure as a precondition for adaptation that through processes of self-production becomes permanently redefined as adaptation, reaching a new steady state of mutual co-adaptation with its environment. This allows the system to anticipate its behaviour, giving it increased capacity to maintain viability.

Internalisation should be seen as a substructural feature of an agency that enables it to adapt, and which is facilitated through autopoiesis. Expressed in terms of necessary and sufficient conditions, accommodation is a necessary condition for adaptation since without it requisite variety is not possible, while assimilation is a sufficient condition that enables accommodation.

2.3. Metacybernetics, Complexity and Recursion

Metacybernetics is deeply connected with complexity [55]—where systems display behaviour that is inexplicable by any conventional analysis of the system's constituent parts. Where complexity occurs in a bounded situation that is distinguishable from an environment, the boundary will be dynamic and involve uncertainty [46]. Data will be conflicting or inclusive, and there will be those who disagree over assumptions or theories, as there will be those who cannot come to any accommodation since their values are in conflict. More, complex situations will be dynamic and evolutionary, and changing contexts are important. Complexity suggests situations that are uncertain and unpredictable, ill-structured in time and/or space, and involves tangles between entities [56] that result in an unordered complicated uncertain state or condition. This idea of tangle implies a lack of knowledge concerning the visible or hidden elements of an observed effect that constitutes an object, and their structural and process relationships. The known and unknown elements and their relationships may be together responsible for the manifestation of an observed effect (as an object), and it is through the identification of the general relationships involved that unknown elements may perhaps be uncovered.

The modelling of complex phenomena to resolve issues through intervention strategies can usefully engage metacybernetics by providing a means by which deeper hidden general relationships may be uncovered. For reinforcement, let us recall that metacybernetic orders are virtual constructs that are reflections of Simon's [8] notion of system hierarchy, the latter being defined as an embedded sequence of related contextual systems. Here, the system is composed of subsystems that in turn may have their own subsystems, etc. In a parallel way, we have used the term metasystem hierarchy to refer to: a family of higher cybernetic orders that occur as *embedded recursive reflexivities*. Each higher order is contextualized through its lower order, this creating a parallel contextual and indeed cognitive hierarchy. Where there is uncertainty in the nature and relationship between entities in a given system, this can be explained through its metasystem. Where there is uncertainty in the relationship between a system and its environment, a higher order should enable this to be reduced.

Metacybernetics embeds a potential for defining a sequential incrementally increasing discrete sequence of cybernetic orders that is described as an embedded recursive reflexivity. To better understand this, consider that by reflexivity is meant a self-relationship (i.e., when a system is defined in terms of itself), and by recursive we mean involving an iterative process. Recursive reflexivity therefore refers to a reflexive relationship that is repeatedly called upon. By embedded we refer to that which exists within, and so an embedded recursive reflexivity refers to higher (*2*nd, *3*rd, . . . *n*th) cybernetic orders.

Therefore, central to metacybernetics is the notion of recursion. However, there are two types [57]: horizontal and vertical. Let us consider each in turn. Metacybernetics involves recursive reflexivity that results in a *metasystem hierarchy*, a form of *horizontal recursion* that is responsible for the generation of higher orders within the hierarchy. It accommodates an ontological structure of cybernetic orders, where in each order general relationships have been recognized that explain a lower order. It is through these that each higher order has the potential to contribute to, and in some way, elaborate on the regulatory process of lower orders. *Vertical* recursion is responsible for the creation of deeper explorations of a system (and/or its metasystem), and is capable of generating more relevant information and hence delivering uncertainty reduction.

3. Philosophical Contexts for Metacybernetics

In this section, we shall distinguish between local and global rationality. Local rationality is connected to the discrete cybernetic orders and the relevance of each as a function of context, while global rationality refers to the philosophical basis upon which metacybernetics rests and is relevant to systemic stability.

3.1. Local Rationality

Lepskiy [26] was interested in the evolution of cybernetics, and in this he explores the cybernetic orders *1–3* in purely local terms. These rationalities are recursively dependent, the higher embracing the next order down. Higher orders come with increasing systemic complexification [58]. Lepskiy's rationalities concern *1*st order objects, *2*nd order subjects, and *3*rd order metasubject, and his interest lies in their relationships that arise through classical, nonclassical and post-nonclassical paradigms (arising from Russian philosophy [59,60]). The distinction between these paradigms is as follows:

(1) In the classical type of scientific rationality, interest lies in the object that is described in detail in a way that is deemed to be independent of an observer who is seen to be value free, this supported by a classical notion of positivistic objectivity, activity in action, and where full and true knowledge can, in principle, always be acquired. Thus, this approach eliminates everything not directly belonging to the object.

(2) Nonclassical rationality centres on the knowledge of an object through inquiry which is influenced by inquirer values and goals, involves ideas of constructivism, and forms of activity such as communicative and reflexive activity (where the agent making an action is also affected by it) can occur. Essentially, for Vladiv-Glover [59], nonclassical rationality refers to post-structuralist thinking in which various critical and

philosophical disciplines are applied to construct a multi-disciplinary theory of consciousness and perception. Zinchenko and Pervichko [61], citing Styopin [62], explain that nonclassical rationality centres on complex systems, where the system of interest is seen holistically, and cannot be reduced to the qualities of its constituent elements.

(3) The broader post-nonclassical type of rationality involves goals and purposes that arise from beyond the theme through social values and goals, and may involve constructivism that involves activity, evolution, engagement and constructive processes that connect with the needs of complex self-developing systems, and the formation of new types of control: through self-developing environments that become dominating, and through "the soft force" that should contain mechanisms of support of the assembly of subjects, and which Dopfer et al. [40] might refer to as meso regulative structures.

Now, it has been noted that *1*st order cybernetics is connected to the positivist paradigm, and concerns the relationship between the subjects in a system with objects in its environment. The *2*nd order nonclassical paradigm operates with self-regulating systems bedded in systemic self-regulation. The *3*rd order post-nonclassical paradigm is complex self-developing systems that have a capacity to adapt and thus develop their character [61]. Following Lepskiy [26], self-regulating system rationality has a subject–subject relationship (involving communicative interaction between subjects). Self-determining system rationality has a metasubject–subject relationship, the metasubject being defined as a self-developing reflexive-active environment. The metasubject–subject relationship requires the metasubject to be seen in terms of subjects and reflex-activity that is a consequence of feedback processes. The distinction between these discrete rationalities is listed in Table 1 (adapted from: Lepskiy [26] and Umpleby et al. [63]).

Table 1. Distinction between three Cybernetics Orders.

	1st Order Cybernetics	2nd Order Cybernetics	3rd Order Cybernetics
Philosophy	Positivism—a posteriori knowledge that is the result of experience	Constructivism—the self construction of knowledge	Humanistic constructivism—involving active, evolving, engaging and constructive processes
Type of philosophy	Classical	Nonclassical	Post-nonclassical
Rationality	Subject–Object (object is an observable effect)	Subject–Subject (subject becomes observer)	Metasubject–Subject (metasubject is reflexive-active)
Nature	Complex system with activity in activity, feedback, hierarchy	Active systems, communicative relations	Self-developing environment, Reflexive activity
Epistemology	Realism where knowledge is directly derived from reality (direct experience rather than observation)	Constructed knowledge is worldview relative, and influenced by methods and means of the subject (as observer)	Knowledge is metasubject dependent, with its values and goals (from feedback of meta-observer: family, group, organization, country, etc.)
Ontology	Behavioural system with external observer	Metasystem–system as *1*st order metasystem hierarchy	2nd stage metasystem hierarchy
Interest	Reality	Reflections of reality	Self-developing reflexive-active environment
Philosophical assumption	Natural processes can be objectively explained by scientific theories	Natural processes are relative to the subject's worldview	Natural processes are relative to (1) the metasubject and (2) understanding of observable structures
Application	Modify natural processes for perceived benefit	Influence the phenomenon being studied	Enabler of coevolution

3.2. Global Rationality

For greater generality that enables innumerable orders in a metasystem hierarchy to be explained rather than bounding consideration at the 3rd order, it needs to be shown that the existence of local rationalities is ultimately dependent on the framing of a global rationality for metacybernetics. This is because if one is interested in identifying any higher orders of cybernetics that lie beyond Lepskiy's considerations, there is a need to understand the boundaries and higher order descriptors that can characterise local rationalities.

Mingers [27] notes that cybernetics operates through critical realism for which the "real world" exists independent from agency perceptions, theories, and constructions. An image of this real world is constructed from agency perspectives and experiences through observation that in a complex world may be flawed due to unobservable structures. Agencies are stable if their understanding of real-world phenomena permits efficacious adaptation to significant changes in environmental conditions. Unobservable structures cause observable events and reality can be understood only if people know the structures that generate events. Critical realism maintains judgemental rationality which, for Isaksen [64], refers to questions that arise from the view that there is an "external" and objective reality. Inquirers seek to understand this externality subject to the constraints relating to, for instance, the relative potential for fallibility of thought and the categories and theories generated. In general, there is also brought into question the worldview of an inquirer, and how to argue a conclusion that is rational in a relativist epistemology.

The rationality of critical realism embodies systemic and holistic concepts such as totality, emergence, open systems, stratification, autopoiesis and holistic causality [27], making it philosophically coherent with the principles that underpin cybernetics. It accepts ontological realism that is usual in the classical rationality of positivism, but also adheres to epistemological relativism. The distinction between ontological and epistemological dimensions of critical realism lies in that: (a) ontological realism refers to the idea that at least a part of reality is ontologically independent of human minds, and (b) epistemic relativism refers to the idea that valid knowledge is context specific and enables justification for a given argument (hence the concept of judgmental rationality).

Critical realism offers a perspective that permits reality to be reclaimed for itself away from the philosophical ideologies such as empiricism or idealism, having been tacitly or explicitly defined in terms of some specific human attribute [65,66]. Reality is determined by the structures that create these effects which exist independently of us, and distinction can be made between experiences, events and causal mechanisms, epistemic process (related to knowledge) and ontology (as types of being) under praxis (practice, rather than theory). For Miller [67], realism conforms to two general and macroscopic aspects, *existence* and *independence*. Existence is a claim that supposes that effects occur (often as material objects) in the external world (that constitutes reality) independently of their being perceived, and the second claim asserts that objects in the external world exist independently of what is thought about them. In other words, critical realism arises because material effects are deemed to exist independently of whether they have been perceived or theorized.

Realists argue that causal processes which arise cognitively mediate perceived appearances. Therefore, objects effectively remain independent, and causal mechanisms distort an observer's knowledge concerning their nature. In realism, theories refer to real features of the world, while reality points to that which is in the universe, such as forces or structures which cause phenomena that are perceived by an observer [68]. Consistent with the realisation that living systems must engage in the creation of some virtual system that enables it to self-regulate through an internalised model (the ideate) of itself in relation to its environmental interactions [4], for Balick [69], external world effects are internalised subjectively, and objects are brought into the subjective agency's unconscious internal world. This then forms an internalised assimilated cognitive object, also called a meta-object by Mielkov [70]. Relationships are then formed with other cognitive meta-objects as well as agency ego. While the object is part of the external objective world, the meta-object is the result of the internalisation with properties that are the result of assimilation. The assimilation may occur through bias due to drastic and hence malevolent filtering, so that the meta-object (as ideate) may result in having unique properties that do not correspond sufficiently well to the object, this influencing any potential for requisite variety.

The relationship between the global rationality of critical realism and those local rationalities of Lepskiy may be illuminated. Rather than considering relations at local levels between metasubjects (including higher order metametasubjects, . . .), subjects and objects, one can introduce the more general notion of the "relational subject" [28], this indicating that agencies and their agents are relationally constituted in so far as they have acquired qualities and capabilities through their internal and external social relations. It has already been said that Donati [28], in discussing relational subjects, explains that they are involved in a meta-reflexivity that within the material world can be explained in terms of system hierarchy (i.e., relating the agent as subject to the collective subject), and thus redefined within the context of the metasystem hierarchy as higher orders of subject.

4. Horizontal Recursion

Horizontal recursion can be used to explore the discrete dynamic systems (having evolutionary—quantitative and qualitative trajectories [13]) that reflect the stability of observational processes. Horizontal recursion is a substructural process that extends causal mechanisms, and these can be validated through the recognition that they involve causal-agents—dynamic elements that produce effects or from which events result, and which have properties that explain outcomes and associations. It occurs in a living system when there is a direct or indirect relationship between a system component that is associated with a metasystem in a metasystem hierarchy, and through which internal regulation occurs. Horizontal recursion is a generator of local paradigms that conform to specific rationalities for 2nd and higher orders, and here we shall consider 2nd and 3rd order cybernetics following on with a principle that extends it to the *n*th order.

4.1. Horizontal Recursion in 2nd Order Cybernetics

To understand the nature of horizontal recursion, we shall first examine an interest of Stafford Beer [9] in modelling the self-organizational mechanisms that living systems engage with, and in doing so we shall distinguish between: an environment composed of all those elements beyond the boundary of a system that are relevant to it; operations (of a system) which include those material components that are responsible for behaviour; and the metasystem which controls the system. The relationship between the metasystem and system can be represented, as shown in Figure 2, as a 2nd order cybernetic construct for which we can differentiate between the environment, the system and the metasystem. The assembly in Figure 2 is one of agency as a domain populated by agents as subjects. Here, agency is composed of a metasystem and a system, with an environment:

- The environment: contains objects with which agents (as agency subjects) interact; other agents (as subjects of other autonomous agencies) interacting in the environment may also be seen as objects from the perspective of a different agency.
- The system: exists through its operations; is considered to have a material ontology since it structures possibilities for behaviour through its agents, as subjects, as they mutually interact *richly*, as opposed to poorly with environmental objects which lie beyond the boundary of the system.
- The metasystem: has a virtual ontology with hidden functionality—not directly observable; it involves metasubjects as observers, and has a structure that can support and regulate the system for systemic benefit; and as a construct it reflects systemic interactive functionality in the environment.

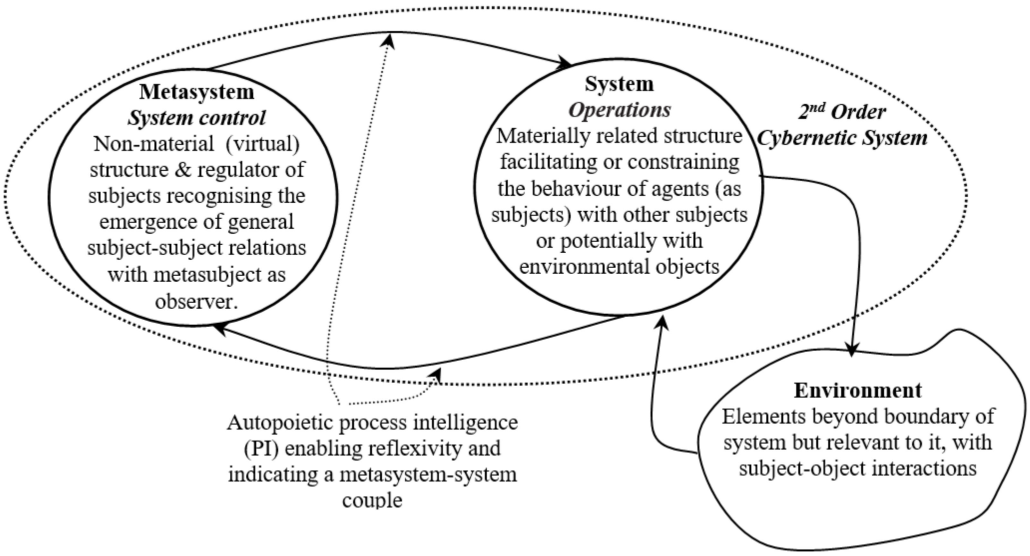

Figure 2. Relationship between System and Metasystem in 2nd Order Cybernetics.

The relationship between the metasystem and the system occurs as a structural coupling that intimately connects them. This coupling (called θ) is significant, this being due to its autopoietic (self-producing) nature which has been argued [50] to be consistent with what Piaget [14] called Operative Intelligence, and which in essence is constituted as a network of processes that we call Process Intelligence (PI).

In Lepskiy's terms, the system has a subject–object rationality as agents (as subjects) within the system act in relation to objects in the environment. The metasystem has interests in the interactions that occur between the agents (subject–subject rationality) from which general relationships may be observed that in due course emerge as regulatory structures. The difference between the system and metasystem is ontologically significant, and permits the claim that the system is physically functional, while the metasystem is virtually functional. In human activity systems beyond 1st order where cognition and consciousness exist, the virtual becomes the psyche.

Now, Miller [71] argues that living systems contain functionally critical subsystems. These, as explained by Schwaninger [10], can contribute to the viability of the system, enabling it to survive. In living systems, viability is facilitated through processes of self-organisation that enable a system to survive in problematic or chaotic situations. Schwaninger has also shown that there is a close connection between the concepts underpinning Miller's living system and Beer's [9] Viable System Model (VSM), in which he defines four components that determine the nature of his metasystem. This is shown in Figure 3, illustrating a 2nd order system (adapted from Yolles [19]). In the same way that Miller explains that there are critical subsystems in a living system, Beer identifies generic subsystems that are necessary and sufficient for the viability of a system. In formulating the connections between these, he differentiates between the system S1 and the metasystem in which he includes S3, S4 and S5. However, questions have been posited concerning where S2 should sit [19]. Here, a metasystem is shown as three generic components (S3, S4 and S5) with an undecided question for S2, where each function has interactive relationships with other functions, and which are together represented in Figure 2. The process intelligence (PI) indicates that all of these interconnections between the metasystem and system can be *symbolically* represented through PI. In the case of S4, there appears to be a direct connection to the environment, but this is not possible since the metasystem is a virtual (non-operative) component of the system, and the connection rather extends from management that may participate in S4.

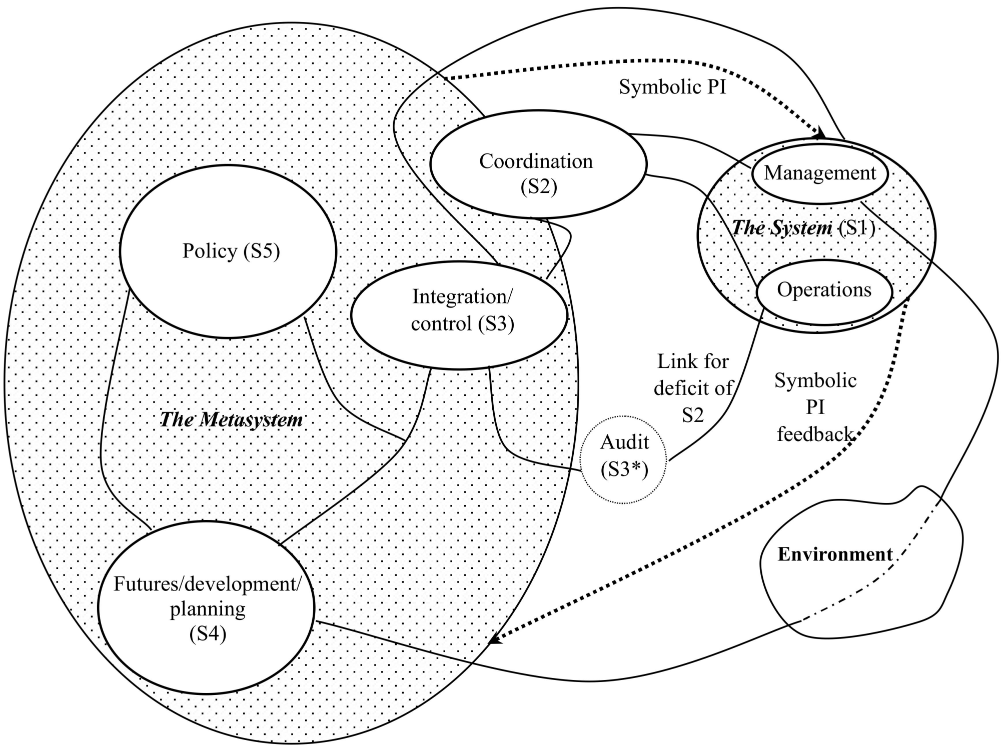

Figure 3. The Connectivity between Generic Functions in VSM.

These five generic functions in Figure 3 may be seen as subagencies, and are defined as:

- S1: The system that defines that which is of interest (the system in focus) and its behaviour. Operations provide a representation of what the system does and produces, and it is usually expressed in terms of its functional units. The system is regulated by S2–S5. Therefore, when it interacts with the environment, it does so through S4.
- S2: Coordination is connected to S1 through feedback, and is an overarching regulatory centre that attempts to harmonize with culture while reducing chaos by creating order, thereby enabling the system to self-regulate its operations.
- S3: Integration is concerned with effective regulation of the dynamic aspects of the organization and synergy, and is in charge of the functional units through controlling and monitoring system operations. It also determines information needs, and has responsibility for the implementation of policies and the allocation of resources.
- S3*: Audit is a subsidiary function to S3, and involves the investigation, evaluation and validation of information flow between S1 and S3, where the link to S1 is simply to collect information deficit associated with S3.
- S4: Futures/development/planning involves the identity of the organization, and has strategic planning interests that are exercised through observation and information gathering from the environment and the system, and the creation of knowledge, this enabling a model of the system–environment relationship necessarily to be a part of S2, for without this coordination would not be possible. Its future orientated tasks include research and development, training (excluding S2 functionality), recruitment, public relations, and market research.
- S5: Policy is concerned with the establishment and maintenance of the coherence of contextual organizational processes and its mission thereby defining the direction of the organization. It provides a systematic capability to choose from different problem situations and/or opportunities in the environment, and is concerned with identity and cohesion, balancing the present and future across internal with external perspectives.

In this model, the autopoietic processes shown in Figure 2 actually exist as a distributed complex tangle of interconnections between the system S1 and the set of S2, S3 and S4, while there are indirect connections to S5. It is because of this tangle that the metasystem–system couple is not totally obvious. While the model is held up as an example of 2nd order cybernetics, it has implicit attributes that are actually 3rd order, and we shall return to this shortly.

4.2. Horizontal Recursion in 3rd Order Cybernetics

Here, we shall elaborate on Beer's VSM in order to postulate a 3rd order cybernetics. The cybernetic system (Figure 4) has three ontologically differentiated systems in a metasystemic hierarchy. The metasystem and system together form an autopoietic couple. This is influenced by the metametasystem.

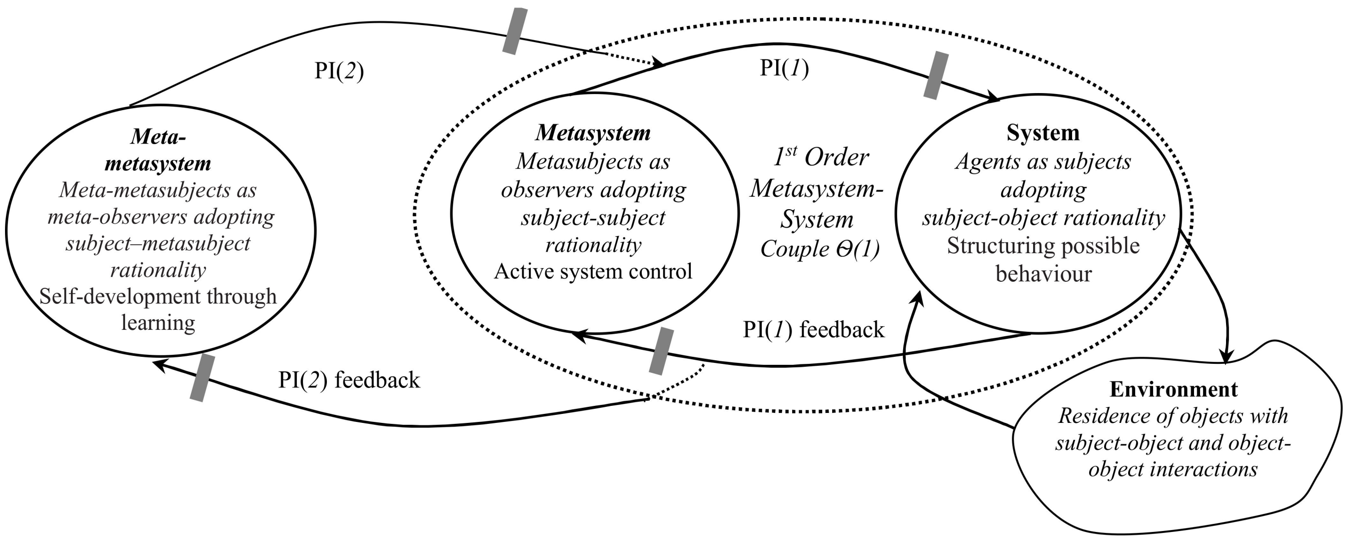

Figure 4. Basic Model for a 3rd Order Cybernetic Living System Involving 3 Interconnected Ontological Distinct Domains in a Metasystem Hierarchy.

Systemic behaviour is determined by the possibilities provided by the structure of the system as imperatives from the environment that demand behaviour. These demands may arise from goal-directed agency needs or wants, or requisite variety responses to (i.e., those that counter) the imperative for change that impinge significantly on the system from the environment. A 1st order paradigm is relevant when there is no apparent metasystem, and behavioural responses are current capabilities of the structure (i.e., structurally determined). In this paradigm, learning is a function of external conditioning which we consider to be a virtual system function that creates a structural response in the system to irresistible factors beyond its control. In other words, such a virtual system is a regulator that is externally determined. In contrast, Dopfer et al. [22] are concerned with evolutionary dynamic systems that are inherently defined in terms of higher order cybernetics (through such attributes as cognitive, legal, political). They consider neither a virtual system nor a metasystem as such, but it is inherent in their discussions.

A 2nd order paradigm is invoked when there exists an autopoietic process intelligence PI(*1*) that has full functionality, but where the autogenetic process intelligence PI(*2*) is blocked. Through PI(*1*), agency is able to self-produce elements of itself, but these are limited to the structural features of its operative system since there is no facility to learn such that novel structural and hence behavioural adaptation can develop. Here, the metasubjects (as observers) operate a subject–subject rationality that derives from general interactive relationships between subjects, thus resulting in regulatory processes as part of the metasystem. Imperatives may arrive from the environment, but these are filtered through the metasystem which maintains an internalised token environment as an *ideate* (e.g., a cognitive model) resulting from processes of accommodation. Thus, in this paradigm agency behaviour is internally controlled. With both PI(*1*) and PI(*2*) functioning, one has a 3rd order cybernetic paradigm where the meta-observer is a metametasubject that adopts a metasubject–subject rationality within the context of self-development. Here, the metametasystem is a meta-observer for the self-production processes that operate in couple Θ(*1*). As in the *2*nd order paradigm, agency behaviour is internally controlled, but the regulatory structures that reside in the metasystem are updated through the metametasystem which maintains overall agency influence. The metametasystem rationality of the *3*rd order paradigm thus enables self-development and system evolution as agency engages in guided constructive self-processes, where the metasubject is reflexive-active and responsible for knowledge and its application.

Now, malevolent information filtering or corrupting pathologies occurring in the process intelligences can explain an effective reduction from a *3*rd order cybernetic system to a *2*nd order one. We reaffirm here that these intelligences are networks of information processes that act as conduits to connect the various internal systems. Consider, for instance, that Figure 3 is a model in which each agency system is concerned with information, and where the types of information involved differ [56]. The metametasystem has identification information (patterns of recognition information related to a given context). The metasystem has elaboration information (schemas relating to a particular goal-directedness determined by a given context). The (operative) system has execution information (operative structures such as role assignment and processes). Each PI now has a task of manifesting information from its source system to its receiving system; however, the transformation may be subject to filtering that can bias observation and challenge the search for requisite variety.

Recall our earlier argument that the metasystem reduces uncertainty for the system through its regulatory structure. This virtual meso structure [22,72] (in which agency is a macro-structure and its agents are micro-structures) is composed of generic rules that regulate the interactive agents, thereby increasing behavioural homogeneity by limiting conflicts and contradictions, and improving order. The meso structure emerges from the general relationships that occur between agents during their interactive events, and hence through emergence provide a representation of these general relationships. However, the metasystem–system couple may also be subject to uncertainty when, for instance, the relationships between elements that are represented in the metasystem are insufficiently well understood. In this case, a reduction in uncertainty requires a higher order metasystem (the metametasystem) that can create a meta-structure for Θ(*1*). As such, the relationships between interactive agents as represented through the metasystem are elaborated through the metametasystem.

The general model in Figure 2 can be used as a framework for an extended VSM (adapted from [19]) as shown in Figure 5. Here, some of the S2–S5 functions are distributed across the metametasystem and the metasystem (note that S3* has been dropped, being merged into PI(*1*)). As before, the tangle of interconnections indicated in Figure 3 between the metasystem components and the system form an autopoietic couple Θ(*1*), and the connections between the metametasystem and Θ(*1*) occur as depicted in Figure 4. However, for this transformation to occur, there is a need to redefine S4 by assigning attributes of observation to S2, expected if the function is to maintain a model of the system–environment. This necessity arises because of the concept of internalisation, where observed objects in the environment are migrated internally to reside in the metasystem, a strategic dimension of the metasystem hierarchy. We shall return to the notion of internalisation shortly.

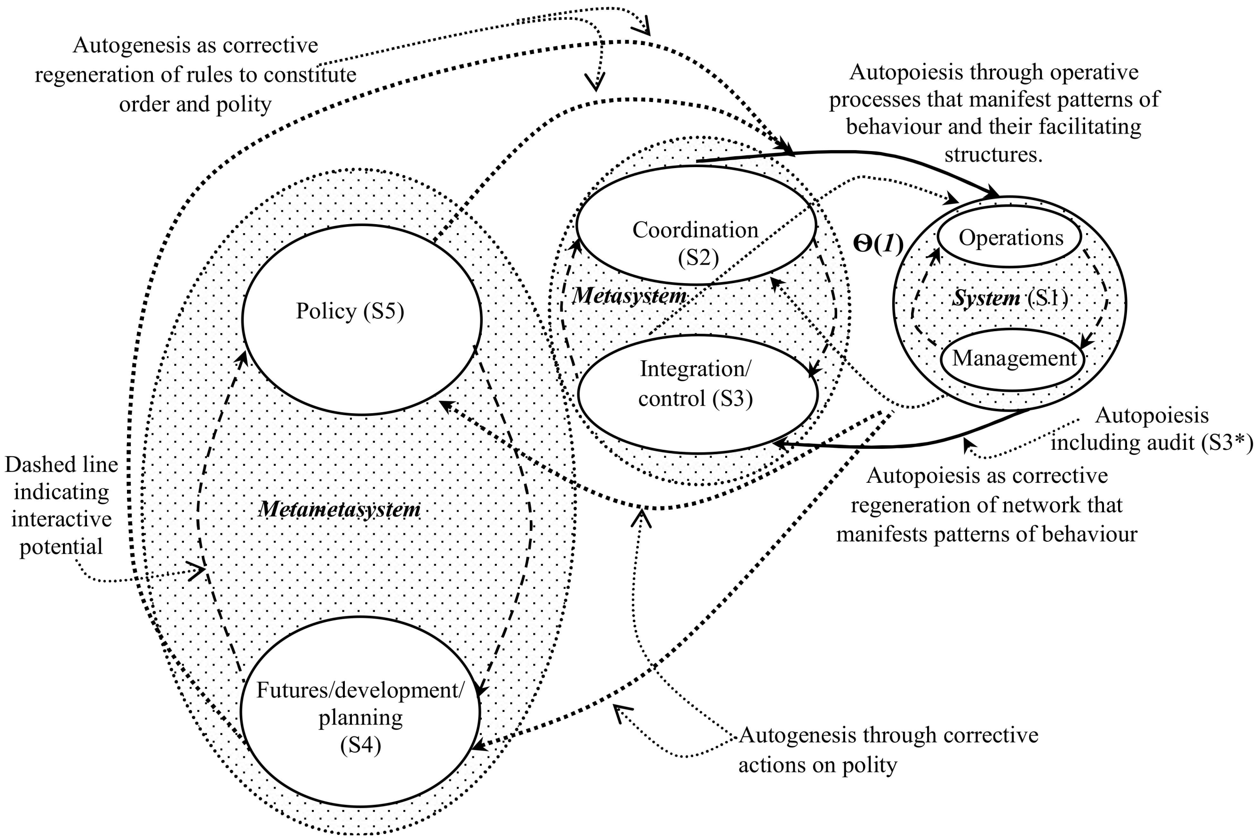

Figure 5. The VSM Migrated into a *3*rd Order Metacybernetic Model.

Suppose that in Figure 5 the relationship between the metametasystem and Θ(*1*) is malevolently filtered or subject to corrupting pathologies, so that the system is unable to suitably adapt. We note that with blockages, only a limited repertoire of system responses is possible, determined by the current structural capacities of the system, and this impacts on any potential for requisite variety [5].

Consider that uncertainty exists in the system concerning S5 policy and S4 planning. To address this, there is a need to explore each of these in more detail, that is, to create a *4*th order metasystem hierarchy. Let us consider that this requires a detailed understanding of the characteristics that compose, say, policy and planning. Now, policy is determined by at least principles and values [73], so that a relationship between these is required that can guide policy in its Θ(*3*) couple. Similarly, S4 planning requires understanding, for instance, with respect to systemic opportunity and benefit [74], and so a *4*th order requires elements that contribute towards understanding - which is meaning related and requires knowledge [75]. Understanding is the result of interaction between meaning and the ideate taken as a token with which to interact and to determine action [76], and this is contained in the metasystem, and in particular it is part of S2 coordination. In other words, it is feasible to construct a *4*th order model for the VSM. Exploring the relationship between knowledge, meaning, values and principles is beyond the scope of this paper. Additionally, rather than creating undue and confusing complexity in representing a *4*th order representation from Figure 5, let us begin with the compressed style of Figure 4, giving Figure 6.

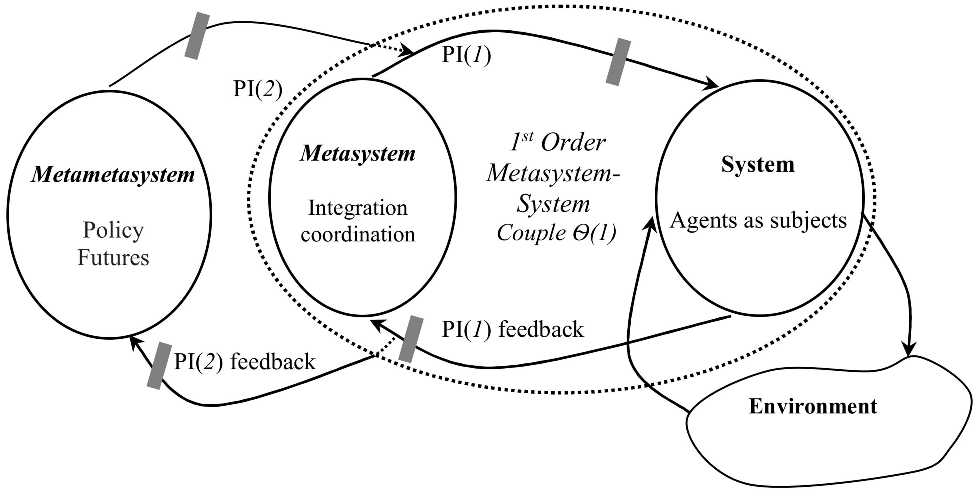

Figure 6. A Simple Representation of VSM with PI(*1*) and PI(2) Embracing the Network of Connections Indicated in Figure 5.

Developing on this *3*rd order system, we deliver a *4*th order in Figure 7. Here, the network of processes PI(*3*) feeds both the meta-metasystem and couple *Θ(1)*. Relative to *Θ(2)*, the couple connecting the metametasystem with *Θ(1)* may be regarded to be equivalent to the 2nd order system of Figure 2 that effectively defines a horizontal recursive and coupling relationship.

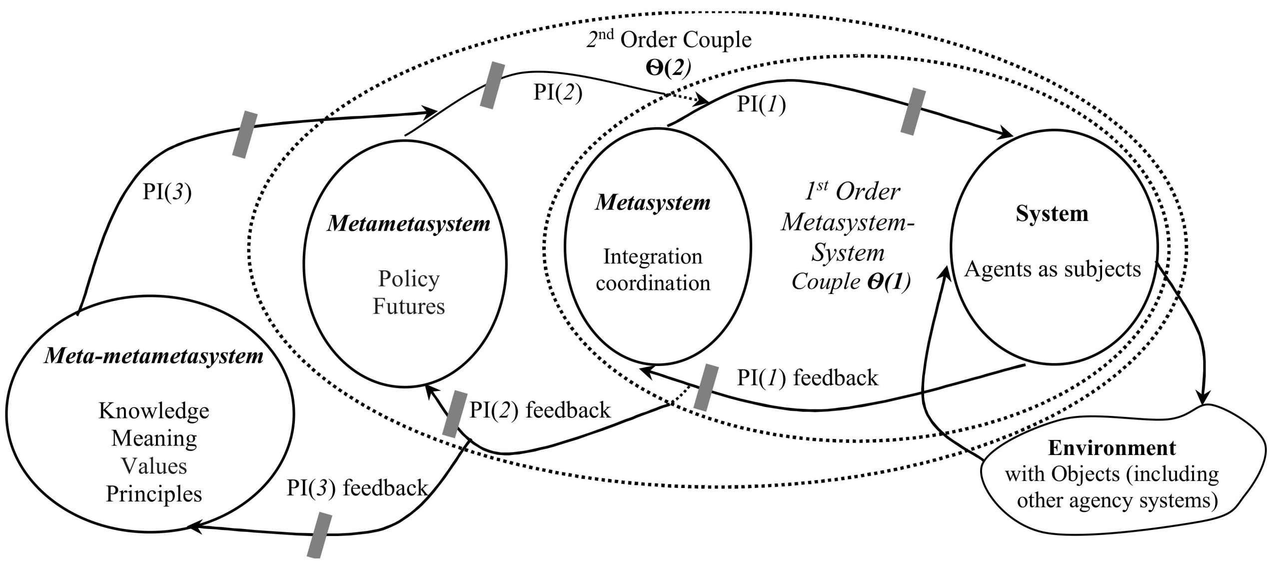

Figure 7. A 4th Order Metasystem Hierarchy for VSM.

We may note that this 4th order model is only feasible if the PI(*3*) is both generic and meaningful (something we shall return to), and there are fundamental issues surrounding this that we shall consider shortly. At this juncture, it is feasible to examine *n*th order metasystem hierarchies in order to explore some general principles of horizontal recursion, before considering vertical recursion.

4.3. Nth Order Cybernetics

Consider that a metasystem is a referent for a system since it refers to strategic goal-directedness and regulative intent associated with a related system. Now, a 2nd order cybernetic system involves a Θ(*1*) that indicates a coupling between a metasystem and its system Process Intelligence PI(*1*), which we recall is autopoiesis that enables self-production when a number of agents interact in order to manifest regulative processes. An illustration of this regulation is the creation of an orientation in a system towards behaviour that likely achieves a goal, where that orientation inherently limits the possibilities of other forms of behaviour. We may apply the idea of a metasystem hierarchy here, enabling 2nd order cybernetics to be extended to higher orders, implied by Piaget [14]. Therefore, a 3rd order cybernetic system is constituted as a second order eigenbehaviour couple Ө(*2*) involving PI(*2*), the latter referred to as figurative intelligence by Piaget. This can be extended through to higher order recursions in Ө(*n*) with PI(*n*). The meanings associated with the PI(*n*) for any *n* will be dependent on the nature of the Ө(*n*), which is necessarily a function of developing modelling context.

Recall that a metasystem can be used to explain the hidden relationships that occur in a system, while the metametasystem can help explain unknown relationships that occur within Ө(*1*). This relationship can be generalised to explain higher order cybernetics in relation to lower orders, as shown in Figure 8 (adapted from Guo et al. [50]). It recognizes that higher order eigenbehaviours can be used to represent the relationship between the PI connected ontologies. Here, then, Ө(*n*) for *n* = *1*, *2*, *3*, *4*, *5* . . . is indicative of 3rd and higher order cybernetic systems. The nature of Ө(*1*) can be defined in terms of the referent system as an *R*(*2*)⇔*R*(*1*) couple, and Ө(*n*) as an *R*(*n*)⇔Ө(*n* − *1*) couple for which R(*n* + *1*) becomes a higher order meta "observer".

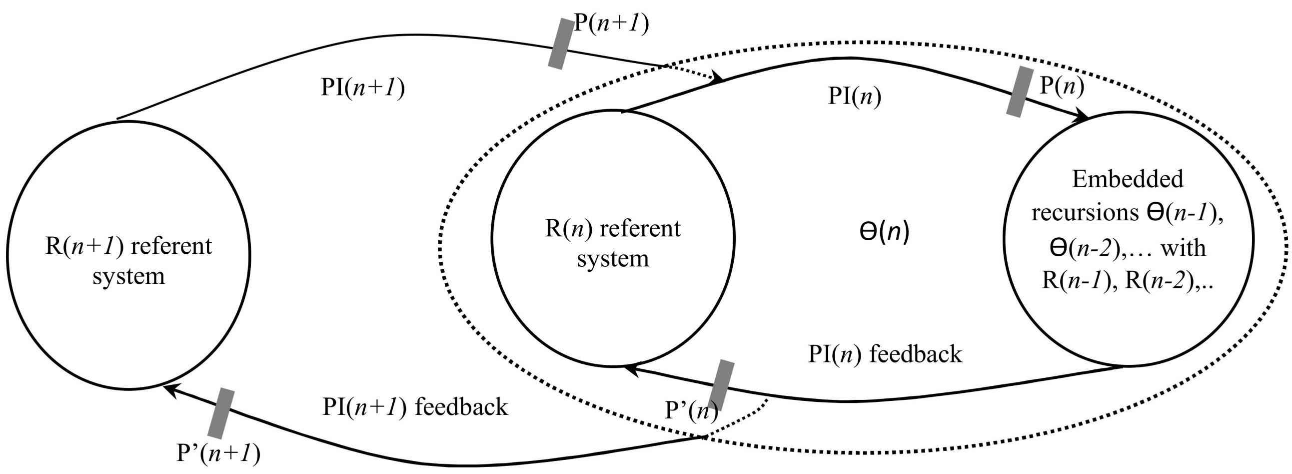

Figure 8. Horizontal Recursion in (*n* + *1*)th Order Metacybernetics.

Pragmatically, given an n^{th} order metasystem hierarchy, how does one determine the nature and meaning of the R(*n* + *1*) referent system? This is not an arbitrary process [77], but rather one that is defined by R(*n*) within the context of the Ө(*n*) couple. Notice the inclusion of the process intelligence pathologies P(*n*) and P(*n* + *1*) and their respective feedback components that can act as biases in the living system, thereby perhaps challenging system stability. This is due to biases or pathologies that are responsible for corrupted or malevolent information flow between the system and its metasystem hierarchy components.

Having referred to system stability, at this stage it will be useful to explain the central importance of Ө(*n*) to living system modelling. In a host of papers, Foerster ([36,78,79]) together with authors such as Rocha [80] and Kauffman ([12,81–83]) introduced the notion of eigenform that explains issues concerning the nature of an object and the perception of that nature, this having significant relevance for the notions underpinning critical realism. This is all to do with the idea of internalisation as explained by Piaget [14], which occurs when that which is observed externally is internally migrated to the observer in a 2nd order system as a token with which it is possible to interact. We recall that the token is an ideate created through information flow by the process intelligences through assimilation and as accommodation.

Internalisation involves higher orders of symbolization in a metasystem hierarchy [84] that can enrich [85] an explanation of a situation. It does so by cognitively elaborating on and transcending observation, this reducing explanation by limiting options, for instance by identifying some options as being contextually illegitimate.

A brief discussion of horizontal stability is now appropriate. Foerster [78] was interested in the stability of living systems for 2nd order cybernetics, expressed in terms of the metasystem–system structural coupling $\Theta(1)$. To achieve this, he introduced the notion of eigenform that discussed the relationship between a subject and object within the context of an observer. A stable living system has an eigenvalue, and when this occurs the metasystem–system couple $\Theta(1)$ has the property of eigenbehaviour enabling self-organisation.

Now, the achievement of stability is an iterative process that enables improving accommodation that can (a) enable its elements to collectively become a good regulator of the system [4], thus enabling it to (b) deliver requisite variety. While Foerster's arguments are beyond the scope of this paper, enough has been said to recognize that Figure 8 constitutes a statement that summarizes the dependency of higher order cybernetics on the stability of lower orders. Such stability is susceptible to regulatory uncertainty, and in any $\Theta(n)$ that involves uncertainty in the relationships indicated in an R(n) referent system, a higher order R(n + *1*) can be sought to reduce that regulatory uncertainty.

This brings us to the point where we will look more carefully at the reduction of uncertainty through material and regulatory vertical recursion.

4.4. The Meaning of Higher Orders

Here, we shall return to the question of whether developing a 4th order model from one of 3rd order is feasible. This draws on the idea that a horizontal recursion is a causal mechanism through which a causal-agent operates. As a metasystem hierarchy generator, it is concerned with conceptual dimensionality. In a given cybernetic space, higher orders arise through the conceptual emergence of invariant generic constructs that promote the rise of local paradigms as considered by Lepskiy. Each time that uncertainty has not been sufficiently diminished to enable a system to generate requisite variety, and $n \rightarrow n + 1$ in R(n) resulting in a new higher order metasystem, there is necessarily a need to connect with a new type of PI that has causal-agent properties, and can also represent a new conceptualisation. We recall earlier that we questioned whether PI(*3*) was sensible as a causal-agent, and to do this we need to explore a little further the nature of the PIs. Considering this further should indicate its feasibility.

In the case of the *4*th order PI in Figure 7, what is the meaning of PI(*3*)? This has been considered by Yolles and Fink [86], who have introduced the term autogenetesis (self-origin), which relates to the origin, development, or causal antecedents of something. Here, then, within VSM, one may be looking at the self-origin of S5 and S4, i.e., that which defines it. Such PIs are functionally relative to the defining (referent) system, where their epistemic natures are understood from context defined by the highest order referent system. Originating information from the ideate in the metasystem (as a part of S2) is directly manifested to the metametasystem from the autopoietic couple $\Theta(1)$, but coded information may also be taken indirectly through the autogenetic couple $\Theta(2)$ to couple $\Theta(1)$. Each of the PI(n) orders has the potential to generate a new family of paradigms, this being capable of simplifying complexity by uncertainty reduction through new higher order generic constructs, and this constitutes a process of emergence.

As illustration of such emergence is the concept of autopoiesis (self-production) in a *2*nd order system and the evolution of the *3*rd order through autogenesis (self-creation). Such emergence can result in paradigm shifts. Thus, consider that each order constitutes a form of generic learning that acts as the basis for a family of paradigm shifts, each offering a new way of seeing. Therefore, according to Li et al. [87], autopoiesis is a concept that has been responsible for a paradigm shift. To consider autogenesis, for Schwalbe and Schwalbe [88] there is no clear view that this constitutes a paradigm shift, but this is probably because of the lack of agreement concerning its nature [89–91]. However, recalling that we have directly connected autopoiesis and autogenesis under equivalence with Piaget's operative and figurative intelligences, and since according to DeVries [92] these notions have created a paradigm shift, so it seems together autopoiesis and autogenesis will create a paradigm shift when the terms become more commonly accepted. Since a paradigm exists when a sufficiently large number of supporters believe this to be the case, the idea of autogenetesis as PI(*3*) is not sufficiently circulated to even consider whether it might constitute a paradigm shift, especially since its significance has not been sufficiently explored.

However, what is indicated is that while it is feasible to consider the general emergence of *n* cybernetic orders, it is highly unlikely that consideration of higher than *3*rd order will be broadly addressed due to the limitation of meaning associated with PI($n \geq 3$).

5. Vertical Recursion

Vertical recursion is a superstructural process that seeks to uncover and explore hidden material or regulatory relationships in complex and thus uncertain systems. It occurs when a living system is able to call on itself directly or indirectly with a potential for continual repetition, and has the characteristics of a fractal—a self-similar self-reflexive symmetry, the use of which can enable uncertainty to be diminished. The pragmatic idea of material recursion comes originally from Stafford Beer, who was interested in exploring the hidden deeper detail that exists in complex systems, explaining that viable systems are (vertically) recursive, and can be modelled to contain viable systems within them through an identical (fractal) cybernetic description in a system hierarchy—referred to as *cybernetic isomorphism* [93] (the term isomorphism meaning a similarity of the processes or structure between entities experiencing similar conditions). However, the same principle applies to a metasystem hierarchy in which deeper regulatory relationships can be sought and uncovered. In general, given that a system has hidden detail at either its system or metasystem level, drilling down into its structures can enable that detail to be exposed. This is the principle adopted in most inquiring methodologies like that of Beer's [9] Viable Systems Model or Checkland's [94] Soft Systems Methodology. In both of these examples, vertical recursion involves a process of digging down into lower system hierarchies in order to gain more information. Beer's approach drills down directly into material constructs (e.g., from higher organisational entities like a division to lower-level departments) while Checkland's drills down into a "cultural stream" by examining social and political analysis relative to a given focus.

Such recursion is a well-known principle when dealing with what we see as complex reality. Let us consider a system S with *n* depths of possible material vertical recursions. The system hierarchy involving such a generalised S(*n*) is illustrated in Figure 9, for some $n = 1, 2, 3 \ldots N$.

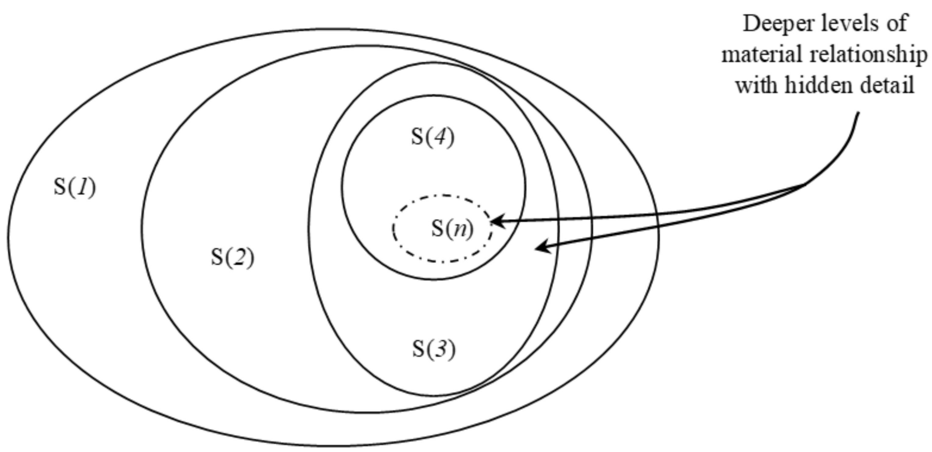

Figure 9. An Illustration of Material Vertical Metasystem Recursion.

We can propose a similar principle for the metasystem–system couple. In this case, one is not drilling down to gather more hidden material information about the nature of a situation and the agent behaviours that occur within it, but rather drilling down in order to obtain more information about hidden regulatory relationships that control those behaviours, and this may be seen as a reflection of the Boisot and McKelvey [7] law of requisite complexity, introduced earlier, since it contributes to the exposure of internal regulative complexity.

To create a generalised relationship, the representation of vertical recursion can be connected to the potential for horizontal recursion within the metasystem hierarchy. Consider the metasystem–system couple shown in Figures 2 and 4. From this we can deduce that any couple Θinherently involves both a horizontal recursion to size h and a vertical recursion q to order v. Here, we take some couple $\Theta = \Theta(h, q_v)$, where $q_v = q_v\{q^1, q^2, q^3, \ldots q^v\}$, where there is a potential for $\{h, q_v\} = \{1, 2, 3, \ldots .\}$. This is represented in Figure 10 for the initial system S(*1*,*1*) under consideration and representing a *2*nd order metacybernetic model showing four vertical recursions. Here, the metasystem is M = M(h, q_v) where $h = 1$ (the limit imposed here is intended to simplify representation) and the bounds on $v = v(1,4)$, and where the couples $\Theta(1, q_v)$ are vertically embedded in the metasystem hierarchy.

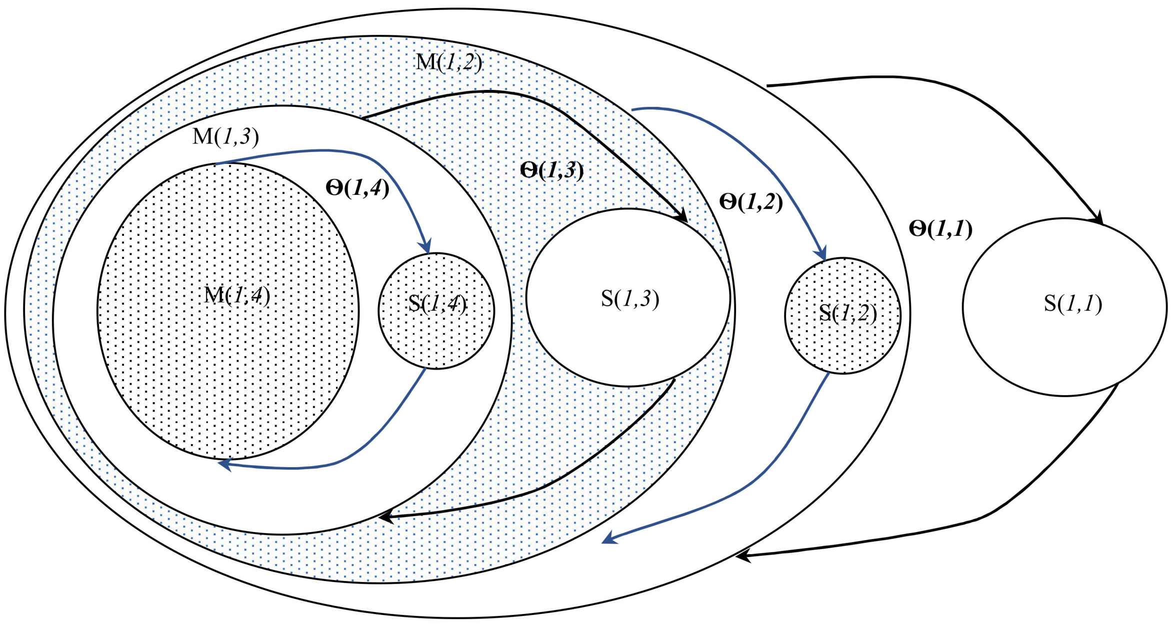

Figure 10. Illustration of *2*nd Order Metasystem Hierarchy with Horizontal Recursion (h) for $h = 1$ Indicated as by $\Theta(1,1)$, and Vertical Recursion (v) for $v = 1, 2, 3, 4$ Involving Variations in $\Theta(1,v)$.

When discussing metasystem hierarchy, one must always recognise that it offers a recursive set of regulative layers that exist as virtual vertical foci, one order having a regulatorily superiority over the one below. All of these layers constitute distinct focal levels of regulation that can ultimately impact on the development of behavioural order. Each regulative layer inherently constitutes a model of the general relationships that relate to those below it, and which contribute to the complexity of the generic meso structures.

Let us now elaborate on this generalised *2*nd order representation to consider a *3*rd order cybernetic model of a living social system, as shown in Figure 11. Here, the system involves cultural and psychic metasystem components that operate as a regulator for the system, the cultural component taking dominance. The psychic system houses a normative personality; this is just like individual personality but with characteristics being normatively created from emergent structures that derive from (subject–subject) agent interactions.

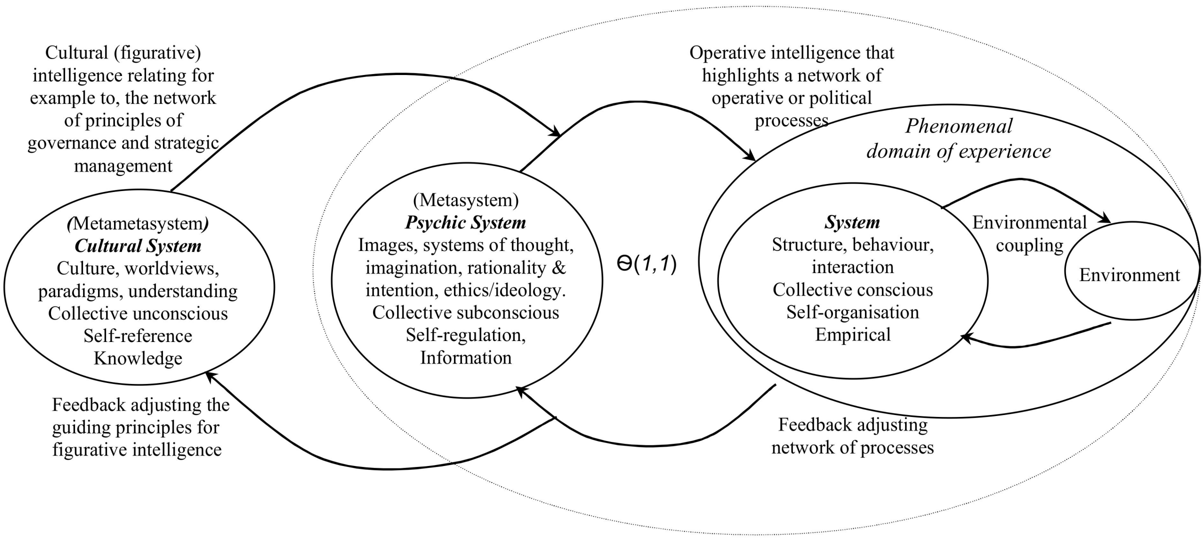

Figure 11. A 3rd Order Model of a Living System.

Consider now that we are interested in exploring the psychic system in more detail. To achieve this, we require a vertical recursion of the 3rd order model, which is a fractal of the base model, with contextual adjustments. This is shown in Figure 12 (adapted from Yolles and Fink [33]). The various intelligences are listed at both recursive levels. This normative personality is thus a recursion (fractal) that interacts with the system through its personality operative system.

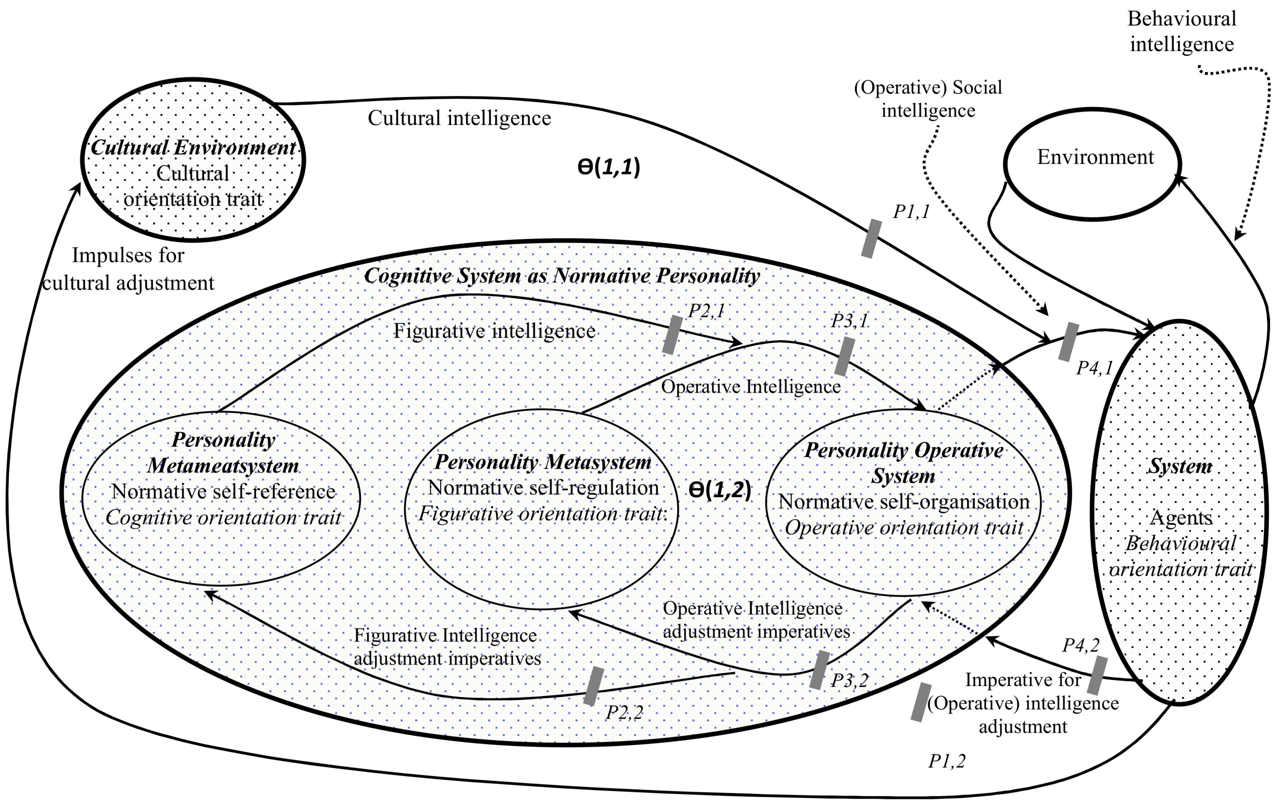

Figure 12. A Vertical Recursion with a 3rd Order Model of a Cultural System and Embedded Normative Personality as a Fractal of the Model.

The system is regulated by both the personality metasystem and metametasystem, the higher order a controller for the lower. The various process intelligences are indicated in Figure 9 which may be defined as:

- Operative intelligence is a network of first order processes which manifests significant figurative information operatively, and can create improvement imperatives to adjust figurative schemas. If isolated in a metasystem–system relationship, instrumental forms of adaptation occur that limit behaviour to possibilities currently built into the system structure.
- Figurative intelligence manifests conceptual information to the metasystem–system couple through a network of second order processes, and this permits novel forms of adaptation to occur through processes of learning that allow for adaptation or creativity.
- Cultural intelligence relates to the ability to function across cultures, and manifests socio-cultural information to the cognitive (and by implication its related affective) agency through a network of third order processes, thus directing it and providing options to adapt to change in socially acceptable ways, while simultaneously able to function efficiently and harmonically through cultural diversity.
- Social intelligence is the capacity to understand and manage others and to behave with wisdom in situations involving human relations in subject–subject relationships. It may be seen to involve awareness that allows one to sense the nature of others, and a social facility that enables one to know how to apply that awareness.
- Behavioural intelligence is the ability to determine appropriate behaviour relative to system needs within given contexts, enabling the selection and execution, as required, of effective (subject–object) behaviour in environmental situations, and may relate to behavioural style (the way in which agents prefer/need to behave and communicate) while embodying principles of emotional intelligence (the ability to understand and manage your own emotions, and those of the people around you), which arises within the personality through both figurative and operative intelligence [95].

Note that in Figure 12, the blocks (malevolent filters/pathologies) Pi,j for pathology type $i = (1,4)$ for cybernetic order $j = (1,2)$, this referring to pathologies that can arise through both intelligence limitation and impeded process efficacy, where efficacy is a measure of the system's capacity to implement metasystems needs (like goals) operatively.

The model also shows traits that are formative in the creation of personality. These are information filters that effectively determine the character and thus the projections of the personality to the system, which ultimately determines behaviour. The pathologies (Pi,j) are able to block or filter information, but this is may be determined by trait orientations. These orientations may take one of two extreme positions, and are non-linear and dynamic being constantly under a process of change, this being reflected in small or even transformational adjustments in personality. The traits are defined in Table 2 (adapted from Yolles and Fink [33]).

We also notice that in the personality system, the interaction between the personality metasystem and the personality system is indicated by $\Theta(1,2)$, one recursive focal level below $\Theta(1,1)$. Adaptive trait adjustments under environmental imperatives may ensure the viability of the system.

A viable system also needs to be stable. In this case, normative processes in the mutual (subject–subject) interaction between agents develop as general relationships which in due course may emerge as regulatory mechanisms for the system. This occurs in the case of Figure 7 through horizontal recursion due to $\Theta(1)$, and for Figure 8 through $\Theta(2)$. Here, it is worth noting that in Figures 8 and 11, stability is more likely to be maintained if culture, which is a dominating systemic influence, is itself stable. The condition of stability arises because culture is deemed to be composed of entities, like values, that might define a homogeneous set when culture is stable. However, when the set is heterogeneous (this arising when values are in conflict), then it becomes unstable. This is reflected in cultural trait functionality that in this case is no longer able to provide coherent direction to the rest of the metasystem hierarchy, and culture loses its domination so that its role as agency anchor is lost. Similarly, the cognitive system creates a personality anchor within the personality. Any instability occurring in the cultural system will leave the personality without any stabilising influence, and this could result in attributes that may not be quite context relevant. Similarly, cognitive system instability will leave the instrumental dimension of the personality without any influencing stability. When the agency it not culturally anchored it becomes an instrumental system incapable of creating knowledge-based novelty.

Table 2. The Nature of the System Traits that Act to Regulate the System.

		Personality Type Enantiomers		
Trait	**Polar Type**	**Nature**	**Alternative Polar Type**	**Nature**
Cultural	Senate	Appreciating nature of needs and ends to be satisfied. Means of satisfaction occurs through exploitation of the external world. Practically orientated, with emphasis on human external needs.	Ideational	Appreciating the conceptual and internal nature of an entity. Creating fulfilment or realization through self-imposed minimization or elimination of most physical needs.
Cognitive	Autonomy	Bounded entities should find meaning in their own uniqueness, encouraged to express their internal attributes such as preferences, traits, feelings and motives.	Embeddedness	Emphasizes maintenance of status quo and restraining actions or inclinations that might disrupt in-group solidarity or the traditional order.
Figurative	Mastery	Monistic in nature and encourages active self-assertion to attain group or personal goals and to master, direct and change the natural and social environment, like values: ambition, success, daring, competence. May involve spontaneous decisions following from the spontaneous desires of the decision makers	Harmony	Pluralistic in nature. Tries to understand and appreciate rather than to direct or exploit. Connected with appreciations driving goal formulation as a process deriving from data collection and involving careful weighing of arguments
Operative	Hierarchy	Relies on hierarchical systems of ascribed roles for productive behavior. Agents are socialized to take the hierarchical distribution of roles for granted and to comply with the obligations and their role's rules. Tends to adopt a chain of authority with well-defined roles. Agents expected to comply with role-obligations putting interests of the organization first. Unequal distribution of power, roles and resources legitimate (values: social power, authority, humility, wealth).	Egalitarianism	Agents tend to recognize one another as moral equals sharing basic interests. Agents are socialized to co-operate and to feel concern for welfare of others. Expectation of action for benefit of others as a matter of choice (values: equality, social justice, responsibility, honesty). Organizations are built on co-operative negotiation among employees and management.
Social	Pattering	Persistent curiosity about the object world and how it works, is constructed, and is named, varied or explored. It is connected to problems of symmetry, pattern, balance, and the dynamics of physical relationships between entities, and is likely to indicate relational connection.	Dramatist	Interested in sequences of interpersonal events, having dramatic or narrative structures that are likely to involve distinction and differentiation (e.g., distinguishing situations), and undertaking effective communications.

6. Conclusions and Discussion

This paper is really the start of an exploration of some ideas that have arisen in the cybernetic literature over the years and which have not really been assembled to produce a coherent picture. Living systems survive by internalising their externality, thereby creating anticipation that determines behaviour [96], and an agency framework has been adopted that reflects this. This framework adheres to a global philosophy of critical realism, while explaining that the rise of individual cybernetic orders occurs through relatable local rationalities. This paper has explained the relationship between different metacybernetic orders in a metasystem hierarchy so as to explore model complexity. It is through this that living system stability and the reduction in uncertainty can be explored. In doing this, the paper initially provides an exploration into the philosophical nature of the framework.

The framework adopted is living system agency theory that, as a general theory, has the dual characteristics of a substructure and superstructure. It was explained that the substructure is connected with system stability and the superstructure with uncertainty reduction. In order to explore the distinction between stability and uncertainty reduction, there was a need to introduce the notions of recursion. Stability, it was argued, can be explored through horizontal recursion. Stability is indicated where there is synergy between an object and the ideate resulting from the internalisation of an of an object that may be reflected at different foci in a metasystem hierarchy. Uncertainty reduction occurs through vertical recursion, when orders in a metasystem and/or a system are examined in order to respectively clarify material or regulatory relationship.

Distinguishing between horizontal and vertical recursion, the former conforms to a deterministic perspective and the latter to a complexity one when considering the stability of a living system. Horizontal recursion arises in a deterministic framework, and can be used to track the discrete dynamic stability of observational processes once a recursion has been validated. As a substructural process causal mechanisms may be extended, and validation of this can occur through the recognition that it involves dynamic causal-agents that produce effects or are associated with events and which have properties that explain outcomes and associations. In contrast, vertical recursion is a superstructural process that reflects complexity, and seeks to uncover and explore hidden material or regulatory relationships in complex and uncertain systems. In living systems, it has the characteristics of a fractal—a self-similar self-reflexive symmetry, the use of which can enable uncertainty to be diminished.

Stability is achieved through a deterministic discrete dynamic process, and is intimately connected with Foerster's ideas of eigenform that explains the relationship between an observed object and its internalised ideate as a token with which the system interacts internally for strategic purposes. This relationship is constituted through the metasystem–system relationship which forms a structural couple that we have called θ. When an eigenvalue exists for θ, then the living system is stable and its capacity for self-production (enabled through its eigenbehaviour) enables it to seek viability. Since living systems operate under uncertainty, to enable them to identify and seek viability they need to be regulated. This regulation is provided by its metasystem hierarchy which emerges from the set of general relationships that exist among its agents. In any metasystem hierarchy there may be n orders, the nth order describing relationships that are relevant to the lower orders. Viability is determined by the capability of a system to adapt, and it does this through processes that are engaged within θ, which in any case may be influenced by pathological filtering (in autopoiesis, for instance), this being capable of corrupting the system and endangering viability.

Uncertainty can be reduced through vertical recursion, allowing a model to drill down into a material or regulatory structure to obtain more detail about aspects of a system, thereby learning more about general relationships.

This paper illustrates how higher orders in a metasystem hierarchy can explain the relationships that exist in lower orders, a situation that essentially abandons the more traditional view that higher orders need to be seen in terms of the observer, or a meta-observer, or a meta-meta-observer, etc., to some *n*th order. While the paper provides a generality that describes *n*th orders in terms of lower (*n-1*), (*n-2*), ... orders, the approach adopted here does not offer a means by which causal-agents can be meaningfully interpreted in the generation of higher orders. Now, all PIs are causal mechanisms, so all of their associated causal-agents must be axiomatic, and thus paradigmatically assumed to exist. Any proposal for higher order PIs therefore requires a process of causal-agent axiom creation. Thus, autopoiesis is now clearly accepted as axiomatic for *2*nd order cybernetic causal-agents [97], Schwarz [47] has argued the same for autogenesis for the *3*rd order, and we have here suggested the same role for autogenetesis as a *4*th order.

Once a causal-agent has been identified and axiomatically accepted, the higher order it is associated with can be used to explore dynamic stability by extending Foerster's eigenform ideas. This has been illustrated by Kauffman [81], showing that if eigenvalues exist then the system is stable and capable of delivering eigenbehaviour. However, applying this to an *n*th order system has been beyond the scope of this paper. More generally, discussion has been concerned with the emergence of *n*th cybernetic orders, where the generation of higher orders can explain lower orders that involve uncertainty. For this, one can use the ideas of necessary and sufficient conditions. That PI(n) is a part of an (n + 1)th cybernetic order identifies it as a necessary causal mechanism, but it still needs to be demonstrated that there is a sufficient condition that it is also a causal-agent of the agency, i.e., it is a dynamic element that produces an effect or from which events result, and that it has properties that explain outcomes and associations. This has been performed in the case of autopoiesis (self-production) and autogenesis (self-creation), and indicated for the case of autogenetesis (self-origin), but arbitrary extensions into PI($n \geq 3$) are inappropriate. In other words, there need to be an appropriate context and significant suitable and detailed explicit and convincing arguments for higher than 4^{th} order cybernetics that might result in a paradigm shift.

Where there is a need to reduce the uncertainty for a particular R(n), (Figure 8) and it cannot be shown that a given PI(n) is a causal-agent (having dynamic properties that produce an effect or from which events result, and with properties which explain outcomes and associations), then one needs to consider whether vertical recursion can be used. Thus, let us reflect on Figure 12, in which the agency has an embedded subagency personality. To explore the meanings associated with the cognitive traits in the personality metasystem, one must first realise that like all such traits, they are dynamic and may change under impetus. One can only generate a PI(*3*) for this if one can explain how it operates as a causal-agent. If interest lies in explaining how a trait attains a value, then it is difficult to see how this involves a causal-agent. Rather, one might drill down to explore the relationships that result in this trait achieving its value. The same approach could apply to the VSM in Figure 7, where one might create a subsubagency model to explore the derivation of S4 and S5.

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