

Radical Constructivism and Radical Constructedness:

Luhmann's Sociology and the Non-linear Dynamics of Expectations

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Abstract

The communication (and reflexive translation) of denotations between semantic domains can generate “horizons of meaning” as reflexive orders that remain structurally coupled to individual minds. Luhmann noted that this elusive order contains a trade-off between “organization” at interfaces integrating (differently coded) expectations at each moment of time, and the potential of further differentiation among symbolically generalized codes of communication in a “self-organization” over time. One can model the coding in the communication of meaning as eigenvectors which evolve as an implication of the interacting intentions and expectations. The interacting horizons of meaning generate new options (redundancy) against the arrow of time, since meaning is provided to events from the perspective of hindsight. Using the theory and computation of anticipatory systems, “self-organization” and “interaction” can be considered as hyper-incursive routines that use (expectations of) future states for their reconstruction, whereas “organization” operates in terms of instantiations (of expectations). Mathematical metaphors can guide us in further exploring the nonlinear dynamics of a social order of intentions and expectations without reification.

Keywords: anticipation, constructivism, sociology, Luhmann, supra-individual

Introduction

In his opening article to a discussion in this journal—entitled “Who Conceives of Society?”—Von Glasersfeld (2008) argued that “knowledge of society can be gathered only from your own experiences. This goes not only for children and innocent adults, it also goes for sociologists.” According to radical constructivism, concepts are fundamentally private and subjective. As the author concluded (at p. 64), his is a theory of rational knowing which provides him with “working hypotheses” (at p. 104).

I agree with Von Glasersfeld about the hypothetical status of subjective concepts. However, working hypotheses can be theoretically informed. Furthermore, whereas hypotheses are generated subjectively—as knowledge claims—they can be validated and become part of discursive knowledge. Discursive knowledge is developed in scholarly discourses; this domain is the subject of science and technology studies (STS). The textual mediation of manuscripts—and anonymous referee comments—play a crucial role in this validation process (Bazerman, 1988; Myers, 1985). However, a focus on linguistic mediation is not a sufficient approach because codes of the communication can be expected to constrain and enable the use of language in communications among specialists for cognitive reasons (Krippendorff, 2008, at pp. 92f.).

Can the evolution of paradigmatically structured systems of communications (Kuhn, 1962) be modeled using the specification of *autopoiesis* as provided by Maturana & Varela (1980, 1984)? In the autopoiesis model, however, the communication is operationally closed, whereas the linguistic basis of scholarly communication leaves

room for relative and periodic closure and/or opening during the evolution of scholarly discourse. For example, pre- and post-paradigmatic phases can be distinguished (Kuhn, 1977; Van den Daele *et al.*, 1977). Thus, a sociological perspective is needed to explain the development of scholarly discourse at the supra-individual level. As Giddens (1976: 144) put it:

The process of learning a paradigm or language-game as the expression of a form of life is also a process of learning what that paradigm is not: that is to say, learning to mediate it with other, rejected, alternatives, by contrast to which the claims of the paradigm in question are clarified.

In my opinion, Luhmann's ([1984] 1995; 1997) sociology of communication offers elements for such a reconstruction because of its focus on reflexivity in interhuman relations. However, Luhmann's contribution to constructivism is rooted in a sociological tradition that can be traced back to the second half of the 19th century. This sociological perspective has focused on networks as coordination mechanisms that are carried by agents who fulfill roles in supra-individual dynamics.

In the *Grundriß* of 1858, for example, Marx formulated most radically that "(s)ociety does not consist of individuals, but expresses the sum of interrelations, the relations within which these individuals stand. As if someone were to say: Seen from the perspective of society, there are no slaves of citizens: both are human beings. Rather, they are outside of society" (Marx, 1973, p. 265). From a (neo-)marxist perspective, Bhaskar (1998, at p. 207) drew the following conclusion: "Now it is important to note

that because the causal power of social forms is mediated through human agency, my argument can only be formally completed when the causal status of human agency is itself vindicated.”

Without explicit references to these non-humanist backgrounds, Luhmann subscribed to the same objective when he drew the following conclusion (e.g., 1990: 275n; my translation): “When, in old-fashioned style, the human being is considered as an ‘element’ of the social system of science, one is left with no basis for the discussion of ‘relations’ or ‘interactions,’ since neither relations nor interactions are human beings.” Using Maturana & Varela’s (1980) theory of *autopoiesis*, however, the realm of relations and interactions is considered by Luhmann as structurally coupled to individual consciousness. Interhuman communication and consciousness can be considered as relevant environments for each other. As we shall see below, in addition to this *structural* coupling, reflexivity in both consciousness and communication is specified as an *operational* coupling between these two domains. Luhmann (2002a, at p. 182) used the word “interpenetration” for this additional coupling.

Let me first focus on structural coupling and Luhmann’s specification of *autopoiesis* at the levels of individual consciousness and interhuman communications, respectively. Consciousness is further distinguished from agency: consciousness is considered as a domain of relations among expectations enabling human beings to process meaning (internally), whereas behaviour and action are attributed to personhood as integrating instances at the individual level (Luhmann, 1991 and 1994). Two steps are thus involved:

firstly, from action to interaction as the basic (micro) operation of interpersonal communication and, secondly, from behaviour to the entertaining of expectations both individually and at the level of one's social network of relations.

In other words, the *explanandum* and *explanans* change positions between the perspectives of radical constructivism and Luhmann's social constructivism. Whereas Maturana (1978, at pp. 53f.), for example, claimed that "denotation is the very function whose evolutionary origin should be explained" and that "language is the necessary evolutionary outcome [...] of a selection realized through behavior [...]," Luhmann positions behaviour—and action—as a reflexive to communication. Communication is considered as a source *sui generis* (Parsons, 1968; Elias, [1969] 2000).¹ Unlike communication in primitive languages (such as perhaps among chimpanzees), however, a symbolic order is prevalent among humans that is both internalized and can be used reflexively for the communication of denotations and connotations—in other words, meaning.

Whereas the generation of denotations can be explained in the biological model—"a second-order consensual domain with other organisms becomes indistinguishable from a semantic domain" (Maturana, 1978, at p. 49)—the semantic contents cannot be communicated reflexively and freely because the biological communication remains

¹ "Plans and action, the emotional and rational impulses of people constantly interweave in a friendly or hostile way. This basic tissue resulting from many plans and actions of men can give rise to changes and patterns that no individual person has planned or created. From this interdependence of people arises an order of *sui generis*, an order more compelling and stronger than the will and reason of the individual people composing it." (Elias, [1969] 2000, at p. 366).

constrained by the *autopoiesis* of the living (cf. Varela *et al.*, 1991). Thus, the denotations are developed in accordance with the development of and resonances among life-cycles. As against Maturana and Varela, Luhmann (1986a; cf. 2002a) hypothesized² that the *communication* of denotations can generate a symbolic order autopoietically. This symbolic order provides us with a second contingency in interhuman encounters: in addition to interactions by observing one another's behaviour, *Ego* expects *Alter* to entertain expectations similar to *Ego*'s own expectations (Luhmann, [1984], 1995, pp. 103 ff.; Parsons, 1951, pp. 91 ff., 1968). The sharing and exchanging of expectations in a double contingency opens "horizons of meaning" (Husserl, 1913, 1929).

Following another lead of Parsons (1968), Luhmann took this theory one step further: the linguistic media of communication can further be refined by codification, and then the symbolic order can structure increasingly a number of (qualitatively different) performative media (Luhmann, 1997). Symbolically generalized media of communication are available for reflexive use by human minds. This second-order capacity for communication, for example, enables us to communicate without needing the use of (natural) language (cf. Habermas, 1987). Non-verbal communication among human beings—unlike communication among chimpanzees—always reflects symbolic mediation (Leydesdorff, 2000). For example, one can pay for a commodity with money without having to negotiate about the price.

² Luhmann often avoided emphasizing the hypothetical status of his theorizing. For example, Chapter 1 of Luhmann ([1984], 1995, p. 12) opens with "The following considerations assume that there are systems." But the author adds immediately: "Thus, they do not begin with epistemological doubt." Elsewhere emphasis is placed on the heuristic function of theorizing and the possibility of combinatorial gains by entertaining hypotheses (e.g., Luhmann, 1977, at p. 49; cf. Leydesdorff, 2010).

Whereas natural languages enable us to communicate meaning within the boundaries, for example, of a linguistic community, symbolically generalized media of communication (such as money, power, truth) enable us to communicate across borders or, in other words, globally. From this perspective, individual consciousness can be considered as a local platform of integration and potential translations among the various media available and continuously instantiated in a pluriform and complex society.

Intentional action can thus be considered as a provisional result of organizing the interfaces among the symbolic media in a local instantiation. Institutional agency organizes the processing of meaning analogously, but at a supra-individual level. At this supra-individual level, however, a mechanism other than “viability” (Stafford Beer, 1984) is needed for continuation over time because the supra-individual level may add an element that cannot be derived from the living without mediation. Luhmann (2000) proposed decision-making among human beings as one such organizing mechanism (cf. Achterbergh & Vriens, 2009).

Mechanisms of integration

What does this superstructure of theoretically informed hypotheses mean for individual consciousness and one’s capacity to radically construct one’s reality? The “horizons of meaning” (such as political meaning, scientific meaning, affective meaning, etc.) are analytically independent of one another and can be expected to operate with different

frequencies. Political communications, for example, are structured by election cycles. Individual consciousness provides us with an additional degree of freedom or, in other words, an internal axis for the integration of the variety of asynchronous and parallel developments across space and time by raising the question of “what do these different dimensions and frequencies mean for me?” The “*me*” can thus be differentiated from the “*I*” within consciousness (Mead, 1934; cf. Bateson, 1972).³

This differentiation within one’s mind and the different possible positions in terms of using communicative competencies makes us reflexively aware that others can be expected to entertain different sets of expectations. One needs to explain and translate into other frames of reference for reflexively understanding interhuman communication.⁴ From this perspective, the domain of expectations provides us with a “second” contingency in which individuals can flourish. The sociological perspective can thus contribute to an “ecology of the mind” (Bateson, 1972) and the sociological project can be reintroduced, but from a humanistic perspective (Luhmann, 2002a and b).

Let me hasten to add that the symbolic orders of expectations at the supra-individual level should not be reified. In my opinion, the symbolic media remain constructs and in flux since constructed autopoietically in terms of expectations of interacting intentions.

Language can be considered first as the evolutionary achievement which allows us to

³ Note that the cybernetic tradition thus differs from the semiotic one as elaborated, for example, in the so-called “actor-network theory” (ANT) of Callon & Latour (1981; cf. Callon *et al.*, 1986; Latour, 1987). The semiotic *actant* is a result of its network of in- and output relations; next-order differentiations are not hypothesized but only considered in terms of observable relations (“co-words”) in the network.

⁴ Luhmann ([1984] 1995) defined understanding as a necessary component of interhuman communication. In my opinion, the concept of “understanding” is anthropomorphic and thus refers to consciousness. I take the liberty to use Luhmann’s concepts in my argument heuristically (Leydesdorff, 2010a).

communicate both information (uncertainty)⁵ and meaning in the same pass (cf. Luhmann, 2002a). Whereas other species can span a semantic domain and “behave linguistically” (Maturana, 2000), the symbolic order enables us to specify understanding and misunderstanding; these reflexive exchanges allow for another order of magnitude in error-correction and learning (Deacon, 1997). The symbolically generalized media of communication enable us, for example, to use jargons in specialties and to pay with credit cards instead of cash. The concreteness of action—observable as physical behavior—can increasingly be replaced by the expression and exchange of meaning using symbols; signatures for example.

Luhmann (e.g., 2002b) cites Husserl as the philosophical source for understanding the results of interactions among intentions as social constructs that shape our cultural expectations. In the *Cartesian Meditations* (1929), Husserl extended the notion of an individual *Ego Cogito* to the plural of *cogitantes*. *Cogitantes* are able to communicate with reference to *cogitata*—that is, objects of doubt. Whereas Descartes assumed that the individual *Cogito* encountered in its contingency the *cogitatum* as Transcendental—that is, God—Husserl “meditated” that this other of oneself could also be considered as the “intersubjective” domain of culture that embeds our psychology, but that can be accessed by *bracketing* the psychological experience. The *cogitata* remain *res cogitans*, but their reflexive declaration changes the perspective to a culturally constructed one. Furthermore,

⁵ Luhmann ([1984] 1995, at p. 67) defined information a selection by a receiving system with a reference to Bateson’s (1972, at p. 315) definition of information as “a difference which makes a difference.” Different from this “observed” information, Shannon-type information can be considered as (meaningless) uncertainty contained in a distribution—as a series of differences (Hayles, 1990; Leydesdorff, 2010a).

the uncertainties at each moment can over time be formulated as expectations and hypotheses; hypotheses can be tested and theoretically informed.⁶

According to Husserl (1934), a “Crisis of the Europe Sciences” had been generated because facts were presumed to be objective, while they remain in the intersubjectively (re)constructed *res cogitans* as theoretically informed hypotheses. Note the analogy with Maturana’s (2000) proposal to consider reality as “interobjectivity.” How can one study this intersubjectivity/interobjectivity as constructed—that is, without reification—and yet empirically? In this context, Luhmann’s (e.g., 1986a and b) contributions can be considered as proposals for further operationalization.

The sociological operationalization of “intersubjectivity”

Awareness of the other as a source of communicable and thus interactively enriching expectations, leads to a discursive and linguistically mediated definition of our social reality. Von Glaserfeld (2008), however, insists on the priority of the question “who conceives of society?” and a focus on the individual constructors: “society” is for him “a collective term for the handful of people we have learned to recognize in the above sense and to whom we may ascribe a number of common characteristics as well as individual differences” (at p. 63). In my opinion, the sociological perspective allows us to distinguish between this specific hypothesis about what I would call a “community” and other possible forms of social organization.

⁶ A hypothesis can be considered as an expectation that is theoretically informed and rationalized.

First, in the interhuman encounter, one can experience what Von Glasersfeld (2008, at p. 61) called a “second viability” if one imputes planning and foresight to others as well as ourselves. The interactions among these expectations—whether linguistic or symbolic—provide the variation for possible further developments of the communication of meaning. When these communications are at first only juxtaposed, “segmentation” is prevalent. Using a biological metaphor, this resembles the *morula* stage during embryonic development: each cell is still complete but no order or hierarchy is yet established.

The transition from the *morula* to the *gastrula* is induced by the need at the level of the emerging organism to synchronize cell cleavages across cells that are no longer adjacent. A rank-order is thus induced by the one cell that happens to take the lead in this process. (Incidentally, this cell grows into the tail and not the head of the organism.) Using this model, recursive relations among communications that are no longer direct neighbours can be expected to induce stratification and hierarchy. A social system of communications in which hierarchical stratification prevails, for example, can be identified as a High Culture (e.g., an Empire). Note the difference with the biological system in the time order: the top of the social hierarchy has “the last word” reflexively (e.g., “*Roma dixit*”), whereas in the biology the first cleavage takes the lead.

The decapitation (in 1793) of the anointed body of the King of France—who was a king by the Grace of God—can be considered as the culmination of a process of modernization that took centuries. The symbolic constitution of the integration of society

was gradually decentered from the embodied King to a system of discourses based on a written constitution. Political communication, for example, could internally be differentiated into a *trias politica* (Montesquieu, 1749). This depersonalization of the constitutive communication paved the way for further differentiation of society in terms of different coordination mechanisms. The organization of society became even more complex because of the possible interactions among these different coordination mechanisms.

For example, the market and political decision-making can be considered as two coordination mechanisms at the level of society. Their interaction leads to a political economy. Possible organizations of these interactions were historically retained among the variety of nation states constructed as political economies (in the plural) during the 19th century. The integration of the social production of knowledge as a third coordination mechanism in the 20th century can be expected to lead to the gradual transformation from political economies to knowledge-based economies (Leydesdorff, 2010c; Leydesdorff & Zawdie, 2010).

The dynamics of eigenvectors of expectations

These coordination mechanisms in systems of expectations can also be considered as eigenvectors in the networks of communications among these expectations (Von Foerster, 1979, 1993a). Note that the eigenvectors remain latent constructs of the communication. However, their position is determined not by single constructors or elements, but by the

set—or, in other words, at a level which is systemic and therefore relatively global to the individual communications (links) and communicators (at the nodes) constructing and reconstructing the system. The causality flows forward and bottom-up with the communications, but the logic of control feeds back from the eigenvectors of the system as a necessary implication.⁷ The relations span a network with necessarily an architecture, and the architecture feeds back on the relational operation.

Furthermore, eigenvectors stand orthogonally to one another, and the number of eigenvectors needed to explain the development of the network is not given. In my opinion, Luhmann used this cybernetic model of a changing and historically variable numbers of eigenvectors to describe the possibility of functional differentiation in a communication system which self-organizes its own reproduction as a regime at the global level (Von Foerster, 1993b). However, Von Glasersfeld (2008, at p. 64, 4n.) noted that this metaphor of eigenvectors is a bit “loose because the recursion of operations is not governed by fixed rules” (as in the static case). The functions develop over time because the system is further developing along historical trajectories.

⁷ Using the following representation:

$$\begin{array}{ccc} A & \Rightarrow & B \\ | & & | \\ A^* & \leftarrow & B^* \end{array}$$

Stephen P. King formulated this relation as follows: “A causes B if and only if B* implies A*” (email contribution to the list of the Cybernetics Discussion Group at <https://hermes.gwu.edu/cgi-bin/wa?A2=ind1201&L=cybcom&F=&S=&P=16432>; January 4, 2012). The topological relation between the two spaces involved is also known as the “Stone duality.”

Historical retention can itself also be considered as one of the functions. “Organization” instantiates the system as relatively integrated for a next round of differentiation. The historical instantiation takes place at specific moments of time, but the functions develop in a self-organizing dynamics over time. Luhmann (2000) suggested that the symbolic medium of organization is decision-making. Decision-making can, for example, be formalized and codified into decision rules.

Organization integrates historically what self-organization tends to differentiate as subsystems at a (hypothesized) next-order level. In addition to these two mechanisms at the systems level, interactions at the bottom provide variation. However, the mechanisms of integration and differentiation can be uncoupled from specific individuals and is organized at a supra-individual level, although the mechanisms of individual actions and interactions remain always needed as a source of variation (Li & Yorke, 1975). Whereas organizations can be shaped over time along historical trajectories, self-organizing regimes develop in terms of combinations of structures in space (that is, as eigenvectors) and time (that is, as eigen-frequencies and their resonances; e.g., Luhmann, 1989); or, in other words, in a hyperspace. Integration and differentiation can operationally be considered as two sides of the same coin: without integrating instantiations, the differentiating communications cannot further be developed at the edge of order and chaos, and thus one would fail to maximize communicative capacity.

From this perspective, the individual mind can be considered as the minimal unit of historical organization. The mind participates in communication as an organizing unit

among other such units—as a medium—and with a possible reference to next-order organizing units. Reflexively, the communication can be integrated and organized into a system of meanings with one order or another. This order depends on the communicative competencies of the communicators and their networks. However, considering the self-organization among the codes of communication as “order” requires a decision, because these dynamics could just as easily be considered as disorder or chaos.

Each description necessarily simplifies the complex dynamics of communication by organizing it. When this integration is organized among individual minds (using an implicit or explicit rule), a specific organization is shaped. When organization of the processing of meaning prevails at the level of society, a High Culture can be expected with a tendency towards a single center of control, and the illusion of cosmological order. However, abandoning the hypothesis of a single center of control provides room for functional differentiation among the different and potentially competing control mechanisms along the eigenvectors of the network. Note that the eigenvectors remain structures of expectation: these *cogitata* cannot be reproduced without *cogitantes*. The social order as an order of expectations remains radically constructed. Its latency can only be accessed reflexively.

The option to organize the system of meaning-processing historically both at the level of the individual mind and at the supra-individual level provides us with another (since social) degree of freedom for the translation. For example, researchers in the laboratory may be able to validate new knowledge that engineers can use in a practical application

for the development of new technologies (e.g., drugs or production processes). A division of labour in terms of combining different codes of the communication is thus made possible because of this “structuration” of the social in terms of structures of expectations (Giddens, 1984; Leydesdorff, 2010b). Each historical manifestation has to be carried by the reflexive performativity of consciousness—whether organized or not—but the reflected symbols can be selected differently with reference to the needs for an intervention in the historical configuration, albeit limited by historical constraints on reflexive understanding and learning.

The symbolic orders can be entertained in terms of fragments and fractals because the integration cannot be completed; differentiation is continuously expected. Derivatives of the Latin verb “frangere” (to break) are more relevant than derivatives of “esse” (to be) because the different mechanisms remain operative. The models thus have to be written algorithmically, that is, as transitions from one state to a next. The description of their cybernetic interactions as a system can be questioned because there may be more systemness in some stages than in others (Krippendorff, 2010).

The hypothesized modification of the autopoiesis model

Luhmann’s sociology requires a reformulation of Maturana’s *autopoiesis* model because the communication of meaning is different from the observable communication of molecules (Luhmann, 1986a). As Luhmann ([1984] 1995, at p. 164) noted, the communication of meaning “*cannot be observed directly, but only inferred*” (italics in the

original). The uncertain and hypothetical character of the communication of meaning suggests an extension of the Darwinian model of variation-selection-retention with the expectation of one more degree of freedom: variation, selection, stabilization, and possibly globalization.

Some selections can be selected for stabilization at the trajectory level. This generates the layer of historical organization in the processing of meaning. Some stabilizations can be selected recursively for globalization at the regime level. Whereas stabilization can be expected to occur along trajectories, de-stabilization, meta-stabilization and potential globalization can lead to regime formation: a symbolic order can be considered. These hypothesized—and therefore knowledge-based—regimes, however, can go into crises and then the system of expectations may move along trajectories to other basins of attraction. The regimes of communication and transitions among them along trajectories can be expected to absorb the creativity in the underlying layers selectively.

In other words and using another biological metaphor, the complexity of communication can be considered as developing parasitically on top of the living systems (Serres, 1980). This parasite, however, is not a viable system and its “living” is contextual because the historical carriers of the communication provide only the medium. The abiotic selection mechanism in communications could perhaps be compared to that of a virus (Distin, 2010).

The selecting structures at the systems level were defined above as the symbolically generalized expectations of codes operating as meta-representations. In other words, the system develops in terms of models that can be entertained reflexively by the modelers. Not the observers, but their observations (that is, observational reports) communicate. The modelers are not only “structurally coupled” as a necessary environment of the modeling, but they also provide the contents because there is no content in these expectations other than expectations generated in interactions among expectations.

Perhaps it is questionable to call a social order that is so rooted in expectations among the carriers a “system” because of its biological connotations and the ensuing tendency in systems theory to reify the dynamics. Unsystematic interactions are crucial for the dynamics because interactions provide the variation (Krippendorff, 2008b). Each description of the social order of expectations as a system may reduce the complexity and volatility by invoking a meta-biological metaphor for the explanation (e.g., “morphogenesis”; Archer, 1995). Given the concurrence of and recursion in selection, stabilization, and globalization, it may be more important to specify the cybernetic mechanisms.

From a cybernetic perspective, the social can be entertained as a radical construct that is continuously being reconstructed. The next-order system remains reflexively available to the carrying systems insofar as one is communicatively competent to access and translate among the differently coded communications. Unlike a “hyper-cycle” with a hierarchy implied in the description, Latour (1988) used the metaphor of “infra-reflexivity” in this

context: there is no “hyper,” “super,” or “sub,” but only interaction among radical constructions each of which can be expected to contain its own (and evolving) eigenvector(s).

The historical and evolutionary dynamics of expectations

In a series of four volumes entitled “Gesellschaftsstruktur und Semantik”—*The Structure of Society and Semantics*—Luhmann (e.g., 1980) further developed what it means sociologically to understand communication as increasingly complex, evolving, and functionally differentiated. He argued that the development of the possible semantics upsets and in the longer run revolutionizes the structure of society because the historical organization has to adapt to the possible dynamics at the global level under the condition of functional differentiation of the symbolically generalized codes of communication.⁸

The invention of the printing press, for example, changed the order of the priority in the communication from the first original manuscript to be copied (e.g., the Bible) to the last-printed version which may have been further annotated, updated, and corrected for printing (or transcription) errors in previous versions. As long as the prevailing organization of society was historically constrained in the cosmology of a High Culture, some communications could perhaps be forbidden, censored, or “ex-communicated”.

However, the Struggle for Investiture in the late Middle Ages opened the Western social

⁸ From the very different perspective of evolutionary economics, Freeman & Perez (1988) developed a similar model of adaptive adjustments in the institutional layer to self-organizing dynamics (cycles) in the market.

system to the possibility of another order of relations between the Church and the Empire based on functional differentiation.⁹ The individualistic revolutions of the 16th and 17th century made it possible to ask questions such as “Who Conceives of Society?”—that is, the question of a concept of reality centered in the *Ego Cogito*.

The dynamics in a contingent communication of expectations are different from Descartes’ transcendental relation with God (Husserl, 1929). While the latter emanates from an origin, contingent communication of meaning is reflexive and mediated; the medium can develop a dynamics of its own. Meaning is provided to the events from the perspective of hindsight. The present is always included. A recursion which includes the present state was named by Dubois (1998) an “incursion.” Incursion and hyper-incursion—that is, the inclusion of *future* states in the development of a system—can be considered as the dynamics of anticipatory systems.

The theory and computation of anticipatory systems

In my opinion, the theory and computation of anticipatory systems enable us to use mathematical metaphors to model the dynamics of expectations, and thus to specify dynamics in the communication of meaning without neglect of the radical constructedness of both the models and the modeled. Rosen (1985) first defined an anticipatory system as a system that entertains a model of itself. As a biologist, he was

⁹ “Render therefore unto Caesar the things which be Caesar’s, and unto God the things which be God’s”, Luke 20:25.

able to specify examples in nature; for example, when plants “know” which phenotype to exhibit in different environments.

Dubois (2003) further distinguished between weak anticipation and strong anticipation. Strong anticipation is the case when a system uses expected states for its own reconstruction; in the case of weak anticipation the expected states are used for the anticipation of possible future states (as in the case of a prediction). In my opinion, the second layer of the double contingency—that is, the one in which contingency among mutual expectations between *Ego* and *Alter* are entertained—can be modeled as strongly anticipatory by using, for example, the hyper-incursive analogon of the logistic equation [$x_t = ax_{t-1}(1 - x_{t-1})$], as follows (Leydesdorff, 2008):

$$x_t = ax_{t+1}(1 - x_{t+1}) \quad (1)$$

In words: *Ego* entertains in the present (x_t) an expectation of itself in a future state (x_{t+1}) modified by the expectation of *Alter* as the other of *Ego* ($1 - x_{t+1}$). This quadratic equation in x_{t+1} has two roots (Dubois, 1998) for values of $a \geq 4$.¹⁰ The uncertainty makes

¹⁰

$$\begin{aligned} x_t &= ax_{t+1}(1 - x_{t+1}) & (1a) \\ x_t &= ax_{t+1} - ax_{t+1}^2 \\ ax_{t+1}^2 - ax_{t+1} + x_t &= 0 \\ x_{t+1}^2 - x_{t+1} + x_t/a &= 0 \end{aligned}$$

In general, the latter equation has two solutions (Dubois, 1998; Leydesdorff & Franse, 2009):

$$x_{t+1} = 1/2 \pm 1/2 \sqrt{1 - (4/a) x_t} \quad (1b)$$

it necessary to take a decision. In the case of double contingency in a reflexive relation, one can perhaps consider this as an update mechanism for the expectations.

Interactions between mutual expectations can similarly be formalized, for example, as two selections operating upon each other using the following metaphor (Leydesdorff, 2010b):

$$x_t = b (1 - x_{t+1})(1 - x_{t+1}) \quad (2)$$

The interaction among mutual expectations thus provides us with an operational order different from the order for each of the carriers (*Ego* and *Alter*) of the double-contingency relations. Whereas Equation 1 uses the expecting systems (e.g., the conscious agents) as systems of reference, Equation 2 models the components of mutual *selections* in interactions between them.

Equation 2 can be elaborated as follows:

$$x_t = b (1 - x_{t+1})(1 - x_{t+1}) \quad (2)$$

$$x_t / b = 1 - 2x_{t+1} + x_{t+1}^2 \quad (2a)$$

$$x_{t+1}^2 - 2x_{t+1} + (1 - x_t / b) = 0 \quad (2b)$$

$$x_{t+1} = 1 \pm \sqrt{x_t / b} \quad (2c)$$

This interaction system oscillates to varying degrees around the value of one (Figure 1). On average, the interaction drifts around $x = 1$ without reaching this value.¹¹ Furthermore, the interaction can be continued for a number of iterations on each side before the alternate oscillation resumes its operation.

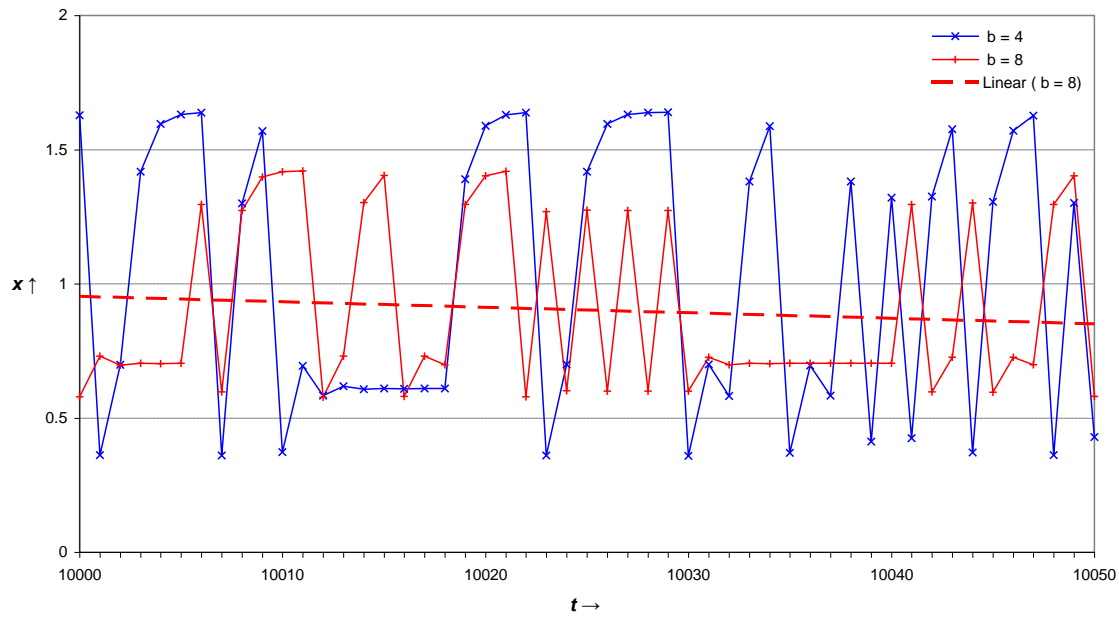


Figure 1: A simulation of hyper-incursive interactions.

In Figure 1, this is modeled in Excel by using a random number to choose the plus or minus sign in the evaluation of Equation 2c. Randomness in the variation warrants the continuation of the interactions. In other words, this stylized simulation enables us to visualize how interactions can serve to generate variation in the *cogitata*. Let us now turn to organization and self-organization as next-order operations in the communication of meaning.

¹¹ The system reaches its largest fluctuations (between zero and two) for $b = 2$, and vanishes for $b < 2$ because the term under the root can then become larger than one, and therefore $x_{t+1} < 0$ in case of the (possibly random) choice of the minus sign in Equation 2c.

The organization and self-organization of interactions

In a next step, Equation 2 can be extended to a one-term more complex configuration of interactions by adding a third selection mechanism. One can add either a hyper-incursive or incursive subroutine, and thus obtain two equations:

$$x_t = c (1 - x_{t+1})(1 - x_{t+1})(1 - x_{t+1}) \quad (3)$$

$$x_t = d (1 - x_{t+1})(1 - x_{t+1})(1 - x_t) \quad (4)$$

Equation 3 is a cubic equation with one real and two complex solutions.¹² Since this system cannot continue its operations further with the complex solutions, it would if left undisturbed by other systems evolve into a single value of the parameter c . This parameter can perhaps be considered as a representation of the code of the communication in this “self-organizing” system. The code dampens the noise in the communication by structuring the system using a third contingency.

¹² The real root of Equation 3 can be derived as (Mike Burke, *personal communication*, 10 October 2008):

$$x_{t+1} = 1 - \sqrt[3]{\frac{x_t}{c}} \quad (4a)$$

The two complex roots are:

$$x_{t+1} = 1 - \sqrt[3]{\frac{x_t}{c} \left(\frac{-1 \pm i\sqrt{3}}{2} \right)} \quad (4b)$$

In general, three contingencies operating selectively upon one another are sufficient for shaping a complex configuration (Strydom, 1999; cf. Yorke & Li, 1975). Note that if only a single fixed code-value c would operate, the routine would tend to self-organize “closure” in terms of this code. In a functionally differentiated system of communications, however, a number of values for the codes can be expected to disturb each other’s tendency to operational closure. Interfaces can be expected to operate in the historical organization of communication.

Equation 4 models organization with reference to the historical present as an *incursive* operation. This equation differs from Equation 3 in terms of the time subscript of the third factor. The reference to the present in this third factor bends the dynamics back to the present state and thus makes the system historical, whereas the self-organizing dynamics of Equation 3 and the interaction system of Equation 2 operate hyper-incursively in terms of interactions among expectations about possible future states. In Equation 4, however, the interaction among expectations is instantiated as a specific historical organization at $t = t$.

The roots of Equation 4 can be derived (analogously to Eq. 2) as follows:

$$x_t = d (1 - x_{t+1})(1 - x_{t+1})(1 - x_t) \quad (4)$$

$$x_{t+1}^2 - 2x_{t+1} + 1 - x_t / [d(1 - x_t)] = 0 \quad (4a)$$

$$x_{t+1} = 1 \pm \sqrt{x_t / d(1 - x_t)} \quad (4b)$$

Simulation of this system shows that the organization of communications always vanishes after a variable number of steps for all values of the parameter d (Figure 2).

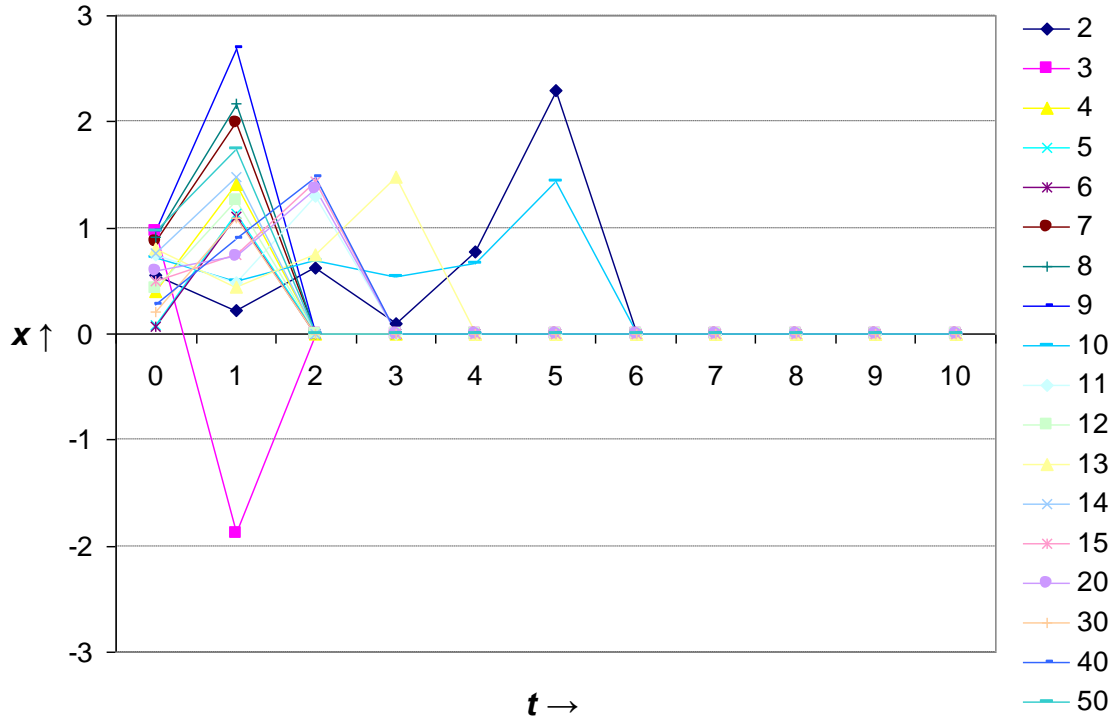


Figure 2: Organization of interactions for different values of the parameter d .

Figure 2 exhibits this development using Excel for the simulation. Excel, however, depicts the historical end of the organization of communications as zeros, but these zeros are based on values of $x > 1$ which lead to a negative value of the denominator of the term under the root in Equation 4b. In this case, the root of this equation becomes complex and can no longer be evaluated. In other words, the organization in the processing of meaning does not disappear because of “dying,” but the historical development of a specific organization can be expected to become insufficiently complex to instantiate self-organization among the fluxes of communication.

In summary, the mathematical metaphors enable us to specify further the dynamics that Luhmann formulated in text. For example, organization of communications of meaning is historical; specific organizational forms can be replaced by other organizations because of the ongoing interactions—introducing variation from below—and the hyper-incursive self-organization of the communication into codes at a relatively global level (Equation 3).

Luhmann (1995, at p. 600n. [1984, at p. 551n.]) formulated a relationship among the three mechanisms in the social coordination of expectations as follows:

“[...] in all social relations, under all circumstances a difference between society and interaction is unavoidable, but not all societies are acquainted with organized social systems. We therefore exclude organizations, but only from treatment on the level of a general theory of social systems. On the next level, that is, of concretizing the theory, one would perhaps need to distinguish between societal systems, organizational systems, and interaction systems and develop separate theories for each type because these three separate ways of forming systems (i.e., dealing with doubling contingency) cannot be reduced to one another.”

Using incursion and hyper-incursion, three analytically different equations (Equations 2, 3, and 4) were derived to model these three (sub)dynamics on the basis of the initial equation (Eq. 1) which models double contingency as the basic operation. Three separate mechanisms in the cybernetics of the social system were distinguished on the basis of the

hyper-incursive formulation of double contingency (in Equation 1) in terms of mutual expectations.

Unlike the hyper-incursive dynamics of interaction and self-organization which operate against the axis of time, organization structures communication historically by using incursion additionally. The three mechanisms can be expected to operate concurrently and continuously, but not necessarily synchronously. The mechanisms update one another. The instantiations thus provide room for supra-individual (e.g., institutional) agency.¹³ Organizations can synchronously entertain sets of different expectations because they are both interfacing different expectations (in the first two terms of Eq. 4) and loop into the present state x_t (in the third term).

Conclusions and discussion

The above formalizations of interaction, organization, and self-organization in the communication of meaning are primitive. In a next step, the equations can perhaps be elaborated into *different* selection mechanisms in x , y , and z as functionally different subsystems that are coupled as sets of differential or difference equations (instead of x_1 , x_2 , and x_3 modeled above as subroutines of a single system x). Such an extension may be able to inform us further about relevant dynamics (Leydesdorff & Dubois, 2004).

¹³ The incursive equation that models action without anticipation of selections at future moments would read: $x_{t+1} = ax_t(1 - x_{t+1})$, and have a steady state at $x = (a - 1)/a$ (in addition to the root $x = 0$; Leydesdorff & Franse, 2009).

I have wished to show how Luhmann's theorizing guided me heuristically in developing the mathematics for systems of expectations. *Res cogitans* cannot (or can hardly) be accessed directly by observing *res extensa*; one can analyze only the footprints of the communication given the retention mechanism (cf. Leydesdorff, 2010d). Conversely, hyper-incursive systems with strong anticipation cannot be identified in nature because the reflexive processing of meaning is specific to our minds and reflexive communications among us.

The radical constructedness of the possible dynamics of expectations presumes the radical construction at the level of the individual mind which was specified most emphatically by the proponents of radical constructivism. Among our concepts, however, we can also entertain expectations about the expectations of others. Building on Husserl's notion of intersubjectivity as the carrying ground for both (inter)objectivity (Maturana, 2000) and (inter)subjectivity (e.g., Luhmann, 1986b) and using other sources such as Parsons' (1951) notion of "double contingency" and the psychological reflections in the pragmatist tradition (e.g., Mead, 1934), two shifts could be proposed by Luhmann: (i) from action to interaction, and (ii) from action as a behavioral category to reflexive perception and experiencing. The internal richness which can thus be perceived correlates with a richer perspective on cultural constructs that can be entertained.

I have pursued a specific line in Luhmann's theorizing which, in my opinion, is available in his writings of the 1980s more than in the later writings of the 1990s. Whereas, for example, Luhmann (1995, at p. 164) emphasized in the first complete presentation of his

theory (in 1984) that “*communications cannot be observed, but only inferred,*” a general theory of observation became increasingly central to his later writings (Fuchs, 2003; Göbel, 2000, pp. 207 ff.; Gumbrecht, 2006; Leydesdorff, 2010a). In my opinion, a differentiation between expectations—based on inferences—and observations that can be used to update (and even test) our expectations provides us with access to, on the one hand, the theory and simulation of anticipatory systems, and on the other, a model of this radical construction that can then be considered as a theoretically informed set of working hypotheses.

The descriptions which dominated Luhmann’s historical analyses can also be enriched with the possibility of statistics about semantic maps and their development in terms of coded structures among eigenvectors in the networks of communication (Leydesdorff, 2011; Leydesdorff & Welbers, 2011). Without damaging any of the assumptions of radical constructivism about the subject-centered origin of concepts, the further elaboration of mechanisms that turn private knowledge into intersubjectively validated discursive knowledge can thus be made visible in terms of the historical organization of meaning in contingent domains.

This sociological analysis potentially enriches our philosophical (self-)understanding as an additional enlightenment about the possible constraints and contingencies of communication (Luhmann, 1998, p. 18; cf. Von Glasersfeld, 2008, p. 64). The specification of the dynamics of expectations may seem as abstract as philosophical reflections, but given Luhmann’s operationalization the epistemological status of our

expectations has changed. Expectations about these dynamics can be rationalized, tested in terms of simulations, and measured in terms of empirical footprints in the development of organizations.

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References

- Achterbergh, J., & Vriens, D. (2009). *Organizations: Social Systems Conducting Experiments*. Dordrecht, etc.: Springer Verlag.
- Archer, M. S. (1995). *Realist social theory: the morphogenetic approach*. Cambridge, UK: Cambridge University Press.
- Bateson, G. (1972). *Steps to an Ecology of Mind*. New York: Ballantine.
- Bazerman, C. (1988). *Shaping Written Knowledge: The Genre and Activity of the Experimental Article in Science*. Madison, WI: University of Wisconsin Press.
- Bhaskar, R. (1998). Societies. In M. Archer, R. Bhaskar, A. Collier, T. Lawson & A. Norrie (Eds.), *Critical Realism: Essential Readings* (pp. 206-257). London/New York: Routledge.
- Callon, M., & Latour, B. (1981). Unscrewing the big Leviathan: how actors macro-structure reality and how sociologists help them to do so. In K. D. Knorr-Cetina & A. V. Cicourel (Eds.), *Advances in Social Theory and Methodology. Toward an Integration of Micro- and Macro-Sociologies* (pp. 277-303). London: Routledge & Kegan Paul.
- Callon, M., Law, J., & Rip, A. (Eds.). (1986). *Mapping the Dynamics of Science and Technology*. London: Macmillan.
- Deacon, T. W. (1997). *The Symbolic Species: The co-evolution of language and the brain*. New York/London: W.W. Norton & Company.
- Distin, K. (2010). *Cultural Evolution: By Means of Natural and Artefactual Languages*: Cambridge University Press.
- Dubois, D. M. (1998). Computing Anticipatory Systems with Incursion and Hyperincursion. In D. M. Dubois (Ed.), *Computing Anticipatory Systems, CASYS-First International Conference* (Vol. 437, pp. 3-29). Woodbury, NY: American Institute of Physics.
- Dubois, D. M. (2003). Mathematical Foundations of Discrete and Functional Systems with Strong and Weak Anticipations. In M. V. Butz, O. Sigaud & P. Gérard (Eds.), *Anticipatory Behavior in Adaptive Learning Systems* (Vol. Lecture Notes in Artificial Intelligence Vol. 2684, pp. 110-132). Berlin: Springer-Verlag.
- Elias, N. ([1969] 2000). *The Civilization Process: The History of Manners*. Oxford: Blackwell.
- Freeman, C., & Perez, C. (1988). Structural crises of adjustment, business cycles and investment behaviour. In G. Dosi, C. Freeman, R. Nelson, G. Silverberg & L.

- Soete (Eds.), *Technical Change and Economic Theory* (pp. 38-66). London: Pinter.
- Fuchs, P. (2004). *Der Sinn der Beobachtung*. Velbrück: Weilerswist.
- Giddens, A. (1976). *New Rules of Sociological Method*. London: Hutchinson.
- Giddens, A. (1984). *The Constitution of Society*. Cambridge: Polity Press.
- Göbel, A. (2000). *Theoriegenese als Problemgenese*. Konstanz: Universitätsverlag Konstanz.
- Gumbrecht, H. U. (2006). Luhmanns intellektuelles Vermächtnis. *Merkur*, 60(8), 696-706.
- Habermas, J. (1987). Excursus on Luhmann's Appropriation of the Philosophy of the Subject through Systems Theory *The Philosophical Discourse of Modernity: Twelve Lectures* (pp. 368-385). Cambridge, MA: MIT Press.
- Hayles, N. K. (1990). *Chaos Bound; Orderly Disorder in Contemporary Literature and Science* Ithaca, etc.: Cornell University.
- Husserl, E. ([1935/36] 1962). *Die Krisis der Europäischen Wissenschaften und die Transzendente Phänomenologie*. Den Haag: Martinus Nijhoff.
- Husserl, E. (1929). *Cartesianische Meditationen und Pariser Vorträge [Cartesian meditations and the Paris lectures]*. The Hague: Martinus Nijhoff, 1973.
- Krippendorff, K. (2008a). Towards a radically social constructivism. *Constructivist foundations*, 3(2), 91-94.
- Krippendorff, K. (2008b). *Organizations as Networks of Conversations and of Stakeholders*. Paper presented at the International Communications Association (ICA), Montreal, May 21-22.
- Krippendorff, K. (2010). Cybernetics and Systems Theory, communication at the Cybernetics Discussion Group at <https://hermes.gwu.edu/cgi-bin/wa?A2=ind1006&L=cybcom&F=&S=&P=1565>; June 9, 2010 (retrieved January 13, 2012).
- Kuhn, T. S. (1962). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
- Kuhn, T. S. (1977). *The Essential Tension: Selected Studies in Scientific Tradition and Change*. Chicago: Chicago University Press.
- Latour, B. (1987). *Science in Action*. Milton Keynes: Open University Press.
- Latour, B. (1988). The Politics of Explanation: An Alternative,. In S. Woolgar & M. Ashmore (Eds.), *Knowledge and Reflexivity: New frontiers in the Sociology of Knowledge* (pp. 155-177.). London: Sage.
- Leydesdorff, L. (2000). Luhmann, Habermas, and the Theory of Communication. *Systems Research and Behavioral Science*, 17(3), 273-288.
- Leydesdorff, L. (2008). The Communication of Meaning in Anticipatory Systems: A Simulation Study of the Dynamics of Intentionality in Social Interactions. In D. M. Dubois (Ed.), *Proceedings of the 8th Intern. Conf. on Computing Anticipatory Systems CASYS'07* (Vol. 1051 pp. 33-49). Melville, NY: American Institute of Physics Conference Proceedings.
- Leydesdorff, L. (2010a). Luhmann Reconsidered: Steps towards an empirical research program in the sociology of communication. In C. Grant (Ed.), *Beyond Universal Pragmatics: Essays in the Philosophy of Communication* (pp. 149-173). Oxford Peter Lang.

- Leydesdorff, L. (2010b). The Communication of Meaning and the Structuration of Expectations: Giddens' "Structuration Theory" and Luhmann's "Self-Organization". *Journal of the American Society for Information Science and Technology*, 61(10), 2138-2150.
- Leydesdorff, L. (2010c). The Knowledge-Based Economy and the Triple Helix Model. *Annual Review of Information Science and Technology*, 44, 367-417.
- Leydesdorff, L. (2010d). Redundancy in Systems which Entertain a Model of Themselves: Interaction Information and the Self-organization of Anticipation. *Entropy*, 12(1), 63-79; doi:10.3390/e12010063.
- Leydesdorff, L. (2011). "Meaning" as a sociological concept: A review of the modeling, mapping, and simulation of the communication of knowledge and meaning. *Social Science Information*, 50(3-4), 1-23.
- Leydesdorff, L., & Dubois, D. M. (2004). Anticipation in Social Systems: The Incursion and Communication of Meaning. *International Journal of Computing Anticipatory Systems*, 15, 203-216.
- Leydesdorff, L., & Franse, S. (2009). The Communication of Meaning in Social Systems. *Systems Research and Behavioral Science*, 26(1), 109-117.
- Leydesdorff, L., & Welbers, K. (2011). The semantic mapping of words and co-words in contexts. *Journal of Informetrics*, 5(3), 469-475.
- Leydesdorff, L., & Zawdie, G. (2010). The Triple Helix Perspective of Innovation Systems. *Technology Analysis & Strategic Management*, 22(7), 789-804.
- Li, T.-Y., & Yorke, J. A. (1975). Period Three Implies Chaos. *American Mathematical Monthly*, 82(10), 985-992.
- Luhmann, N. (1977). Differentiation of Society. *Canadian Journal of Sociology*, 2, 29-53.
- Luhmann, N. (1980). *Gesellschaftsstruktur und Semantik: Studien zur Wissenssoziologie der modernen Gesellschaft I*. Frankfurt a.M.: Suhrkamp.
- Luhmann, N. (1986a). The autopoiesis of social systems. In F. Geyer & J. v. d. Zouwen (Eds.), *Sociocybernetic Paradoxes* (pp. 172-192). London: Sage.
- Luhmann, N. (1986b). Intersubjektivität oder Kommunikation: Unterschiedliche Ausgangspunkte soziologischer Theoriebildung. *Archivio di Filosofia*, 54(1-3), 41-60.
- Luhmann, N. (1989). *Ecological communication*. Chicago, IL: University of Chicago Press.
- Luhmann, N. (1990). *Die Wissenschaft der Gesellschaft*. Frankfurt a.M.: Suhrkamp.
- Luhmann, N. (1991). Die Form "Person". *Soziale Welt*, 42(2), 166-175.
- Luhmann, N. (1994). Die Tücke des Subjekts und die Frage nach den Menschen. In P. Fuchs & A. Göbel (Eds.), *Der Mensch – Das Medium der Gesellschaft?* (pp. 40-56). Frankfurt a.M.: Suhrkamp.
- Luhmann, N. (1995). *Social Systems*. Stanford, CA: Stanford University Press.
- Luhmann, N. (1997). *Die Gesellschaft der Gesellschaft*. Frankfurt a.M.: Suhrkamp.
- Luhmann, N. (1998). *Observations on modernity*. Stanford, CA: Stanford University Press.
- Luhmann, N. (2000). *Organisation und Entscheidung*. Opladen: Westdeutscher Verlag.
- Luhmann, N. (2002a). How Can the Mind Participate in Communication? In W. Rasch (Ed.), *Theories of Distinction: Redescribing the Descriptions of Modernity* (pp. 169-184). Stanford, CA: Stanford University Press.

- Luhmann, N. (2002b). The Modern Sciences and Phenomenology. In W. Rasch (Ed.), *Theories of Distinction: Redescribing the descriptions of modernity* (pp. 33-60). Stanford, CA: Stanford University Press.
- Marx, K. ([1857] 1973). *Grundrisse: foundations of the critique of political economy (rough draft)* Harmondsworth: Penguin.
- Maturana, H. R. (1978). Biology of language: the epistemology of reality. In G. A. Miller & E. Lenneberg (Eds.), *Psychology and Biology of Language and Thought. Essays in Honor of Eric Lenneberg* (pp. 27-63). New York: Academic Press.
- Maturana, H. R. (2000). The nature of the laws of nature. *Systems research and behavioral science*, 17(5), 459-468.
- Maturana, H. R., & Varela, F. (1980). *Autopoiesis and Cognition: The Realization of the Living*. Boston: Reidel.
- Mead, G. H. (1934). The Point of View of Social Behaviourism. In C. H. Morris (Ed.), *Mind, Self, & Society from the Standpoint of a Social Behaviourist. Works of G. H. Mead* (Vol. 1, pp. 1-41). Chicago and London: University of Chicago Press.
- Montesquieu, C., (1748). *De l'esprit des lois*: Paris.
- Myers, G. (1985). Texts as knowledge claims: The social construction of two biology articles. *Social Studies of Science*, 15, 593-630.
- Parsons, T. (1951). *The Social System*. New York: The Free Press.
- Parsons, T. (1968). Interaction: I. Social Interaction. In D. L. Sills (Ed.), *The International Encyclopedia of the Social Sciences* (Vol. 7, pp. 429-441). New York: McGraw-Hill.
- Rosen, R. (1985). *Anticipatory Systems: Philosophical, mathematical and methodological foundations*. Oxford, etc.: Pergamon Press.
- Serres, M. (1980). *Le parasite*. Paris: B. Grasset.
- Stafford Beer, A. (1984). The Viable System Model: Its Provenance, Development, Methodology and Pathology. *Journal of the Operational Research Society*, 35(1), 7-25.
- Strydom, P. (1999). Triple Contingency: The theoretical problem of the public in communication societies. *Philosophy & Social Criticism*, 25(2), 1-25.
- Van den Daele, W., Krohn, W., & Weingart, P. (1977). The political direction of scientific development. In E. Mendelsohn, P. Weingart & R. Whitley (Eds.), *The social production of scientific knowledge* (pp. 219-242). Dordrecht: Reidel.
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: MIT Press.
- Von Foerster, H. (1979). Cybernetics of Cybernetics. In K. Krippendorff (Ed.), *Communication and Control in Society* (pp. 5-8). New York: Gordon and Breach.
- Von Foerster, H. (1993). Für Niklas Luhmann: Wie rekursiv ist Kommunikation. *Teoria Sociologica*, 2, 61-85.
- Von Foerster, H. (1993). Über selbst-organisierende Systeme und ihre Umwelte *Wissen und Gewissen* (pp. 211-232). Frankfurt a.M.: Suhrkamp.
- Von Glasersfeld, E. (2008). Who conceives of society? *Constructivist Foundations*, 3(2), 59-64.