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Reinterpreting self-organizing and self-sustaining Knowledge Reproduction Processes in Organizations:

A complex and autopoietic Systems Perspective

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The wind blows where it wills

John 3:8

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For some, the journey is more important than the destination. For others, it is only the end goal that matters as it both an end in itself and an incentive for boundless search. But I was lucky enough to not have to choose between the road and the end goal: I had my eyes set on the horizon line. The Strategic Management and Innovation team ensured that it always stayed this way and for this, I will be always grateful.

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0. Abstract

Organisations need to acquire knowledge in order to survive in the environment. They encode their experiences into routines and enact these routines according to environmental changes and demands. However, this path-dependent and linear conceptualisation of knowledge is not without its challenges. Namely, knowledge is a double-edged sword that can damage existing routines and capabilities if organisations do not have the necessary structures to accept novel information. This work aims to propose an alternative framework for knowledge acquisition and organisational learning. The argument follows the principles of autopoiesis theory: organisations are able to reproduce their own knowledge with no direct reference to the environment. A central claim of the present work is that such self-reproduction processes are aided and supported by defective knowledge and flawed learning processes. Namely, these flawed learning processes display particularities that allow organisations to amplify and customize their experience of the external world. The second part of this work explores this claim further by documenting coordination of complexity in multimorbidity care. The aim is to highlight self-organizing processes that allow healthcare actors to perceive and manage complexity through a relative ignorance of existing interdependencies. This work will thus serve those knowledge theorists who are interested in non-linear mechanisms of knowledge reproduction and creation.

0 Résumé

Les organisations ont besoin d’acquérir des nouvelles connaissances afin de faire face aux changements extérieurs. Elles aspirent à encoder leurs expériences sous forme de routines afin de pouvoir les mettre en œuvre en fonction des contingences extérieures. Toutefois, cette conceptualisation linéaire de la connaissance présente quelques difficultés. En effet, la connaissance est une arme à double tranchant qui peut endommager les routines et les capacités existantes si les organisations ne disposent pas des structures nécessaires pour accepter de nouvelles informations. Ce travail propose donc un cadre alternatif pour l'acquisition de connaissances et l'apprentissage organisationnel. L'argument principal se réfère aux principes de l'autopoïèse : les organisations reproduisent leurs propres connaissances sans référence directe à l'environnement extérieur. Ces processus d'autoreproduction sont soutenus et même amplifiés par des structures de connaissance et d’apprentissage imparfaits, voire défectueux. En effet, bien que déficients, ces processus d'apprentissage ont des particularités qui permettent aux organisations d'amplifier et de personnaliser leur expérience du monde extérieur. La deuxième partie de ce travail approfondit cette affirmation en explorant la coordination de la complexité des soins dans le domaine de la multimorbidité. L'objectif est de mettre en évidence des processus d'auto-organisation qui permettent aux acteurs de la santé de percevoir et de gérer la complexité par une ignorance relative des interdépendances existantes. Ce travail servira donc aux théoriciens de la connaissance qui s'intéressent aux mécanismes non linéaires de reproduction et de création de connaissances.

1. Introduction

Why do organizations need to learn? The very fact that such a question appears both intrusive and redundant is a testament to the pervasiveness of learning in the domain of organisation science. In general terms, learning is defined as acquiring new knowledge that in turn, results in new ways of processing information relative to the type and range of experience (Gross, 2016). Learning is considered to be an existential need for the organisation. Without learning, organizations cannot respond to changes in the environment (Levinthal and March, 1993), cannot gain a competitive advantage and more importantly, are not able to survive (Levinthal, 1997). Learning is thus considered to be the main, if not the only, strategy of organisational survival. However for some decades, organisational learning was the battlefield between "visionaries" and "sceptics" (Friedman et al., 2005). Sceptics wonder how organisations are able to learn at all, given the difficulties in learning from experience and the inescapable impact of various cognitive biases (March, 1991). By contrast, visionaries highlight the virtues of the "learning organisation" where organisations in general, and their members in particular, have a boundless capacity to learn in every direction and in every domain of activity (Senge, 1990).

While theoretical opposition is less stark in current organisational learning research, the dispute between visionaries and sceptics has left a particular legacy. From the "sceptical" point of view, the organisational learning field retained a certain distrust of new, incoming knowledge. New knowledge can threaten established, valuable routines (Murray and Donegan, 2003) or increase uncertainty since organisations are not always equipped to deal with new types of information (Lipshitz and Strauss, 1997). Knowledge is something external that has either a negative or a positive potential. Thus, the focus is on the ways organisations can protect themselves from "bad knowledge" and retain their structural integrity. Research on loosely coupled

organisations stipulating that organisations construct a buffer space between themselves and the environment is an example of this "sceptical" legacy.

At the other side of the spectrum, the heirs of the visionaries' perspective argue that knowledge creation across various types of experiences, domains, and subjectivities produce change and reduce uncertainty (Nonaka & von Krogh, 2009). In this sense, knowledge is neither good nor bad per se: it is justified and thereby inherently tied to people who hold it in the first place (von Krogh and Grand, 2000). That is to say, people justify those observations they consider true on the basis of their observations. Once other organisations members share and evaluate this justified knowledge, it becomes embedded in routines. Justified knowledge does not need to be stored at all: knowledge as "knowing" is already a situated process that doesn't need location (Hofer and Pintrich, 1997). Knowledge is thus internal to the organisation because it is embedded and encultured in organisational structures. However, knowledge (and the routines that contain it) should also be projected outside of the organisation either through routine enactment or through adaptation strategies to the environment. Otherwise, organisations would not be able to renew their routines and would be stuck in their own internal, organisational culture (Seidl, 2004).

However, there is some contention on the extent to which knowledge (and thus learning) can be embedded. Namely, some researchers consider that knowledge can never be truly justified in relation to environmental observations (Riegler, 2006). This is because the environment does not contain information and knowledge per se: rather the environment just exists as it is (Foerster, 1970). Hence, while it is still possible for knowledge to have some degree of potential bounded truth, it could never be fully justified. Therefore, the solution may be to consider knowledge as something internal while learning could be best described as the constant reproduction of organizational routines and capabilities (Luhmann, 1990). However, this raises another set of issues that go beyond the opposition between skeptics and visionaries. Namely, if organizations learn by reproducing their routines and generate information for their own constructed environment (cf. constructivist accounts on cognition), can organizations truly learn something new? Or are organizations simply constantly re-learning what they already know?

The answer to such concerns can be found in the evolutionary perspective of organizations. Namely, the variation of routines does not necessarily result from direct external environmental pressure (Yi et al., 2016). Instead, routines are retained by their organizations because of their characteristics (such as salience) (Annosi et al., 2020). These routines are then reproduced but no reproduction of routine is accurate and similar. Each routine reproduction is different and this very difference is what brings novelty, both in knowledge and in learning. However, such small incremental changes are difficult to trace because it is impossible to know whether subjectively appropriated knowledge is embedded enough in order to have an effect on the actions and beliefs of the organization (Yi et al., 2016). Fortunately, it is easier to trace "faulty" knowledge and learning bias in organizations. The issue is not that "faulty" knowledge is more embedded in organizations than "legitimate" knowledge. Rather, the embeddedness of faulty knowledge is more evident because it has very specific consequences for organizational actions (e.g. organizations can fall in competence traps by choosing a previous action with a successful outcome, even this success was not related the action in the first place) (Heimreiks, 2010).

Thus, this dissertation will document how organizations reproduce faulty, vanishing or incomplete knowledge while still learning and acting in their environment. The principle of this approach is that one understands best the value of a phenomenon through the extent to which the manifestations of this phenomenon differ from the accepted norm. In other words, knowledge reproduction processes and learning become more understandable once that they are evaluated in the context of faulty knowledge and learning biases.

This cumulative dissertation will thus evaluate the processes of knowledge reproduction in organization in two sections. **Section A** consists of a solo contribution by the doctoral candidate and refers to *Essay I*. The focus of this section is how superstitious learning and autopoiesis theory allow organizations to construct an environment from which they could learn. Autopoiesis theory shows how organizations can reproduce their knowledge (included in routines, decisions and communications) with no reference to an external, falsifiable environment. Superstitious learning allows organizations to enact routines by structuring

comparisons between internally reproduced routines and the anticipations of what these routines could look like in an alternative environment.

Section B of this dissertation explores knowledge reproduction processes through complexity theories. *Essay II* is mainly developed by the doctoral candidate with Dr. Shiko Ben Menahem as a co-author. Essay II explores how clinical and non-clinical actors collaborate together on multimorbidity care. In so doing, it relies on the complex adaptive systems (CAS) framework. In particular, it outlines how non-clinical health actors at a hospital department provide an environment for coordination and workflow. Healthcare providers build on these scaffolding in order to determine appropriate care strategies for multimorbidity care. The main implication for knowledge reproduction is that non-clinical actors are able to indirectly coordinate and structure knowledge with which they are not familiar with. *Essay III* is mainly developed by Dr. Shiko Ben-Menahem with the doctoral candidate as a co-author. The doctoral candidate was mainly involved in data collection and data coding. Essay III documents how perceived case complexity (i.e. factors related to the patient) impacts health care providers perceptions of care complexity (i.e. factors related to care scheme strategies). In terms of knowledge reproduction, the main insight is that it depends on perceptions of controllability.

The plan of this dissertation will unfold as follows. In **Part I**, I will outline the theoretical framework and the research focus for Sections A and B. Part I will also include a methodology section, a summary of the three essays and a Limitations/Conclusion section. **Part II** will include all essays (Essays I, II and III). Finally, the Appendices will include extracts from interviews in Essay II as well as my Curriculum Vitae.

1. Research Framework

A) SECTION A - Autopoiesis theory

Initially, autopoiesis theory was applied to the biological domain in general and to living systems in particular (e.g. cells reproduction) (Maturana et al., 1994). Autopoiesis refers to a system that can reproduce and sustain itself. Namely, an autopoietic system is a recursive, autonomous and self-producing unity that contains component-producing processes (Varela, Maturana and Uribe, 1974). These processes in turn, produce components that are needed to maintain the mutual action and self-reproduction of the autopoietic system. Thus, the main characteristic of an autopoietic system is that it functions by itself by reproducing its own components. An autopoietic system is thus *organizationally closed* because it regulates its boundaries by and for itself (von Krogh and Roos, 1995). Moreover, autopoiesis theory enforces a distinction between the organization and the structure of the system (Luhmann, 1986). A change in the organization will change the identity of the system while a change in the structure won't.

Luhmann (1986) reframed the autopoiesis theory so that it could be applied to social systems. He argued that organizations consist of decisions and communication that are constantly reproduced by the system. This reproduction allows organizations to differentiate themselves from their environments (Luhmann, 1990). Since systems are organizationally closed, organizations can observe and indirectly "sense" their environment only through a constant reproduction of internal decisions. In other words, an autopoietic system perceives its environment by perceiving itself (Koskinen, 2013). Hence, a system (and the organization it includes) accepts perturbations of the environment as long as these perturbations derive from the system itself (Zeleny, 1981).

The crucial implication for organizations is that their interactions with the environment, their modes of operations, their learning and their components are structurally predetermined. This predetermination is related to the identity of the system. In the biological world for instance, some plants are constrained by their very

structure to reproduce a specific type of flowers. However, if these plants begin to produce leaves instead of flowers, then their identity will be fundamentally altered (Seidl, 2004). Similarly, organizations are restricted to reproduce their components (including routines, communications and decisions) according to *decision premises*. Decision premises are conditions that determine decision contexts (Seidl, 2014). For instance, a program for manufacturing toothbrushes won't generate decisions about making a car.

Thus, the autopoiesis theory questions the modalities under which organizational learning takes place. The accepted notion (developed by the Carnegie School) on organizational learning is that organizations learn by processing inputs from the environment (March, 1991). Organizations then encode these inputs into routines and modify these routines according to external environmental feedback (Feldman and Pentland, 2003). By contrast, an autopoietic organization does not have access to an external feedback. Since organizations have to self-referentially reproduce their own components and decisions, some researchers wonder if any new knowledge can be acquired at all (King, 1993). Because of its self-referential interpretation of knowledge acquisition and learning, the application of autopoiesis theory in management science remains controversial. For instance, Swenson (1992) argues that autopoietic models are completely decoupled from the physical world and thus, could not be used for any practical application in organisational science and learning. By contrast, some researchers (e.g. Von Krogh and Roos, 1995) suggest that autopoiesis can be a new paradigm for knowledge creation.

Essay I contributes to this debate by exploring how autopoiesis theory reinterprets the nature of organizational learning. In particular, I will argue that autopoiesis theory proposes an alternative framework for organizational survival in general and knowledge acquisition in particular. Namely, dominant perspectives on organizational learning (such as the Carnegie School) specify that the external state of the world is the ultimate arbiter of what constitutes true and justified knowledge (Gavetti, et al., 2007). This is because organizations are organizationally open: they depend on external input that they cannot control (Argote and Greve, 2007). Organizational learning thus relies on the maintenance of control in order to preserve a homogenous and coherent identity (Keinan, 2002).

By contrast, autopoietic systems do not need to have a contact with the environment in order to maintain their identity (Magalhaes and Ron Sanchez, 2009). Because organisational components (such as decisions) are reproduced recursively, social systems (such as institutions) become closed and autonomous models of communication while still exhibiting interdependence (Espejo et al., 1996). Organisational learning is thus not about justifying knowledge by comparing it to an objective reality. Instead, organisational learning is about how organizations can observe themselves and thus construct an environment from which they could learn (Luhmanm 1986).

B) SECTION B - CAS - Complex Adaptive Systems

Complex Adaptive Systems (CAS) refers to systems that operate according to self-organisation principles (Cillier, 2005). Namely, the behaviours of the systems components and agents are determined by local rules. As a result, the system components are not aware of the order they are generating (Eppel and Rhodes, 2018). Because agents in CAS engage in non-linear interactions, the outcomes of these interactions are impossible to predict (Blaikie, 2007). Small effects can result in major effects and vice versa. For instance, the adaptation process of patients generates new properties and new emerging living conditions that cannot be explained through their elements (such as life plan and living environment) alone (Stacey, 2003). Another important characteristic of CAS is that self-organized actions from system agents always result in a common goal (sometimes called attractor in the literature) (Cillier, 2005). In this sense, CAS always end towards a state of order.

CAS is part of a broader range of complexity theories and as such, is widely applied to a range of different contexts. Indeed, a characteristic in this field is that complexity is defined according to the phenomena of interest (Stacey, 2003). In healthcare for instance, complexity is defined as an interrelationship between two or more systems (e.g. a misalignment between patients' needs and services) (Kannampallil et al., 2011). The CAS framework is often applied to coordination strategies under conditions of uncertainty (Surana et al., 2005). In particular, the focus is often on

coordination between different specialists in organisations (Nugus et al., 2010) and teamwork strategies in healthcare (Ramos-Villagrasa et al., 2018).

However, direct applications of the CAS framework to healthcare systems are not necessarily straightforward. Namely, focusing on interactions between agents (rather than on the agents themselves), does not really give an understanding about what exactly these agents are doing in the first place. It becomes difficult to determine how people actually learn within complex system at an individual level (Tuffin, 2016). The issue is not trivial because training and learning are crucial steps in sensitizing healthcare practitioners to care and case related complexities (Sweeney and Griffiths, 2002). The self-organization of complex adaptive systems also ensures that one can never be sure about which kind of knowledge the learner acquires in the first place. This is because in CAS, the coordination between system agents and reciprocal learning are only modestly correlated (Hitchcock et al., 2013). *Essay III* fills this gap by highlighting care providers intentionality: their individual perceptions of controllability modify the structure and the nature of care complexity.

In CAS, learning and coordination are thus related but separate constructs. Namely, it is possible to learn while not coordinating with others (Holland, 2006). The reverse is also true: it is possible to coordinate without learning. For instance, junior doctors do not always have a clear understanding of the concept of complete medication reviews (Jubraj et al., 2015). This does not prevent them to coordinate and consult with their supervisors on domains that relate directly to medical reviews such as medication prescriptions. In other words, they coordinate around medication reviews (or at least on concepts related to them) but they do not learn much about medication reviews themselves.

Such discontinuity between coordination and learning in CAS theories suggest that the application of complexity constructs lacks consistency (McKelvey, 1999). Namely, despite the fact that CAS ignores intentionality, complexity theorists tend psychologize complexity and transform CAS into theories of shared decision or collective decision making (Stacey, 2003). In this context, *Essay II* attempts to explore how CAS theories can take in account the intentionality of healthcare practitioners involved in multimorbidity care. In so doing, Essay II relates to recent

research on uncertainty and complexity, where healthcare actors calibrate and adjust complexity and uncertainty according to their needs (Griffin and Grote, 2020).

In this context, Essay II focuses on two CAS theories namely, stigmergy and chaos theory. Both theoretical approaches provide an understanding on how clinical and non-clinical actors can interact together.

(a) Stigmergy

Stigmergy is a model of emergent coordination where system actors interact with each other through the traces they leave in the environment (Borgo 2006). Initially, stigmergy theory was related to pheromone traces left by termites that allow other termites to participate in nest construction (Grassé, 1959). For humans, this means that system actors perform an action that leaves a trace in a shared environment of the system (Marsh and Onof, 2007). This trace allows other system actors to "sense" the effect of the action and thus to act on it towards a common goal. The outcome of such indirectly coordinated actions changes the shared environment in which system actors operate.

Stigmergy principles are often used to explore multidisciplinary team behaviour and task performance (e.g. Mardsen, 2013). In healthcare, it is often used to explore coordination strategies and goal orientation in medical care teams with different specialisations (Crowston et al., 2017). Another field concerns trace-based communications in complex care contexts. For instance, Cristancho and Field (2020) showed that trace based, non-verbal communications in acute care teams are temporally bound because they are important only in the first minutes of acute situations.

The stigmergic model sees knowledge as essentially collective and specifies an increasingly expanding pattern of meta-memories where this knowledge can be processes and located (Kannampallil et al., 2011). This means that knowledge can be reproduced because it is projected outside of the social system in which it first originates. Intentionality is not negated but rather expanded to contexts to which the individual would not have access otherwise. *Essay II* shows how non-clinical actors

rely on stigmergy principles in order to provide an environment of coordination for care providers.

(b) Chaos theory

Chaos theory is part of the CAS framework because it relies on principles of self-organisation and non-linearity. Chaos theory stipulates that from a point of maximum energy (i.e. the initial condition), the system reaches either an aperiodic or a stable equilibrium state and thus acts as an attractor (Rickles et al., 2007). When a system reaches an aperiodic state, the slightest change in the system state will cause the state to diverge: if I place a pencil on its tip and remove my hand, the pencil will fall. Hence, feedback processes can amplify small changes into larger changes. When positive feedback exceeds a critical threshold, this results in a phenomenon of an altogether different scale and quality in comparison to everything that preceded it.

In terms of complexity management in healthcare, chaos theory reinterprets the lack of control, unpredictability and disorder as normal, integrative parts of the care process. Chaos theory has attracted the attention of the shared decision making literature in healthcare and patient counselling literature (Hayward and Prestonm 1999). In particular, the point where feedback reaches a critical threshold is often assimilated to joint decision-making (Bussolari and Goodell, 2009).

Chaos theory can be thus used to understand how medical teams can handle multimorbidity-related complexity. Namely, the level of urgency of a condition determines the setting in which it takes place (Sellnow et al., 2002). This interaction is what constitutes the initial condition towards equilibrium. At this point, care interventions lead to patient activation that, in turn, causes progressive accumulation. Over time, small changes (such as a successful task performance) affect the whole care program until the positive feedback received exceeds the positive threshold (Arndt and Bigelow, 2000). At this point, care providers are able to reach a coherent decision that puts the care system into an aperiodic state.

However, care systems (or in this case care programs in multimorbidity care) are not necessarily conducted in settings related to the condition at hand (Smith et al., 2012).

This is particularly salient in multimorbidity contexts where the coordination of various hospital environments are involved. That is to say, there is a separation between the urgency of the condition and the setting in which it occurs (e.g. a patient may be cared for in the cardiology department but the urgency relates to another condition for instance, the level of insulin). This separation between settings and urgency constitutes the initial environment for care systems (Sellnow et al., 2002). Separate care interventions (e.g. administration of a different medication) leave traces in the environment and thus activate it for further actions. Care providers from different specializations are thus able to coordinate together on complexity through their interventions. More importantly, the feedback loop in chaos theory ensures that care strategies can be successfully reproduced in other settings (Bussolari and Goodell, 2009). *Essay II* builds on such insights in order to understand how care providers can make the best out of the feedback provided by non-clinical actors.

2. Research Focus

A) SECTION A – Superstitious Learning

In organisational learning literature (OL), learning is a process where organisational routines (e.g. rules, procedures and beliefs) are transformed over time (Levinthal and March, 1993). Organisations learn by encoding inferences from past experiences into routines that, in turn, guide behaviours (Levitt and March, 1988). Superstitious learning (SL) occurs when *"the subjective experience of learning is compelling but the connections between actions and outcomes are unspecified"*(Levitt and March, 1988, p.325). Both learning and superstitious learning are defined as routine based, target oriented and path dependent (Winter, 2000). In both types of learning, behaviours, actions and routines depend on the relation between the outcomes observed and the aspirations to those outcomes (Collinson and Cook, 2006).

Superstitious learning derives from an erroneous perception of cause-effect associations between two independent events (Zollo, 2009). However, faulty causal associations are not the only possible explanations. For instance, people resort to superstition in the face of unstable and ambiguous situations in order to maintain a sense of control (Rozin et al., 1986). To some extent, the emergence of superstitious learning is inevitable because it is rooted in the fundamental ambiguity of performance outcomes in organisational tasks (Zollo and Singh, 2004).

The organisational literature often argues that superstitious learning negatively affects the performance of acquired firms through the creation of confidence traps. However, there is some possibility that superstitions do not act directly on firm processes. One of the reason for this, is that superstitions are rarely recognised as such, at least as far as firm settings are concerned (Tsang, 2004). As a result, superstitions never stay alone and highly depend on institutionalised practices and actions in organisations for

their very existence. This suggests that the real impact of superstitious learning cannot be fully grasped through causal explanations alone.

(a) Sources of Superstitious Learning

In the organizational learning literature, there are four general explanations for the occurrence of superstitious learning. First, superstitious learning is interpreted as a *contingent, causal and path dependent process*. Organisations learn by responding to stable environmental conditions (Levitt and March, 1988). Because of this stability, the knowledge that the organisation extracts from the environment is objective, measurable and generalizable. The operational perspective argues that individual learning is entirely shaped by environmental conditions and stimuli (Murray and Donegan, 2003). For instance, Skinner (1941) noticed that pigeons developed idiosyncratic behaviours (such as head turning) when food was presented to them. These behaviours persisted even if the food was given at regular intervals. Thus, the behaviours of these pigeons became conditioned: despite the fact that there was no relationship between their behaviours and food delivery, they still acted as if there was a causal relationship between the two. In other words, the main conditions for superstitious learning are chance and contingency.

Second, superstitious learning is an outcome of *experience ambiguity*. Because our cognitive system exhibits weaknesses in the integration of experiences, past experiences are misinterpreted which in turn, leads to superstitious learning. For instance, Weick and Quinn (1999) note that records of past experience and the subsequent allocation of attention resources reflect a cognitive impossibility to review events from another perspective. Managers frequently derive inadequate lessons from experience and erroneously generalise past experience to inappropriate situations (Haleblian and Finkelstein, 1999).

Third, superstitious learning is also an expression of outcome *ambiguity and control*. Namely, difficulties in interpreting past experiences are mirrored in the failures to perceive complex and unpredictable environments. For instance, Zollo (2009) emphasised that the problems in causality inferences are generated by outcome ambiguity especially when rare and novel strategic decisions are concerned. An outcome-based account of superstitious learning revolves around the notion of outcome ambiguity, that is, the degree of uncertainty that arises when one assesses the outcomes after a given decision or an execution of a given task. This uncertainly arises from novel strategic decisions because their outcomes cannot be measured along clear, objectively predefined criteria.

The issue of outcome ambiguity is often explored in research devoted to competitive advantage. This is because it is notoriously difficult to predict success or to define the criteria of that success (Cooke-Davies, 2002). Namely, outcome ambiguities result in a confidence-competence-paradox. In tasks where the outcomes are defined by fuzzy criteria, the levels of confidence are negatively correlated to the levels of actual competence and accuracy (Heimeriks, 2009). Outcome ambiguities are also related to control bias. Namely, superstitious learning occurs because people prefer to have a sense of control on the situation they find themselves in. People prefer regularities in their environments and if these regularities are absent, they may resort to faulty causal explanations in order to reduce complexity and ambiguity (Torgler, 2007).

Finally, superstitious learning can be seen as a *contextualisation and a disambiguation process*. Namely, experience is not a source of cognitive bias but rather, the result of evolving processes of actions and interpretations. What matters is not the amount of prior experience but rather the type of experiences concerned (Sirmon and Hitt, 2003). Namely, actors construct a "grammar" through their actions that allow others to make sense of the prevalent norms and to create causal maps of past experiences (Hernes and Bakken, 2003). People create the world around them first by enacting it and second, by selecting meaningful features from it. Learning

outcomes and paths are thus never fixed because the knowledge that informs it is actively created by individuals (Weick, 1991).

Accordingly, a part of the decision-making literature highlights the importance of superstitious learning in clarifying the meaning of past experiences. There is a complementarity between superstition and decision-making (Miller and Taylor, 1995). This complementarity arises from the fact that uncertainty and ambiguity are relative concepts. Uncertainty is experienced differently by different individuals and what constitutes uncertainty itself may vary in relation to culture, tolerance to stress and propensity towards hypothetical thinking (Lipshitz and Strauss, 1997; Eisenhardt and Martin, 2000).

In a management context, an uncertain situation arises when managers face well understood but undifferentiated alternatives which are all equally attractive (Tsang, 2004). Superstitious learning can thus be used in order to differentiate between these alternatives and reduce uncertainty. Because superstitious learning automatically picks contingent and temporally close cause and effect links, potential alternatives and uncertainty are reduced. Superstitious learning involves both a degree of risk and potential benefits because it is impossible to determine in advance whether SL causal links are beneficial or not (Barbero et al., 1995).

(b) A Fitness perspective

Superstitious learning (SL) is too costly to abandon if the causal relationship it supports turns out to be valid (Staddon and Simmelhag, 1971). Considering alternative relationships may be simply too risky when decisions are to be taken in terms of uncertainty (Einhorn and Hogarth, 1981). According to this logic, a match between a capability and an opportunity in the environment may bring competitive advantage in the long term, even if it is based on SL.

In the fitness account of adaptation, SL is retained because it is a specific-purpose cognitive mechanism rather than a general one (Cosmides, 1989). SL is the object of

natural selection because it allows organisations to make a quick decision in the face of uncertainty. Jinks (2011) for instance, suggests that an animal with a superstitious pattern of automatic responses is more likely to survive than an animal which cannot rely on such a pattern. Effective enactments and applications of routines should thus depend on a single, specific purpose mechanism that selects those routines that could replicate "successful" behaviour. In a path-dependent way, competition leads to variation among replicators and some of these variations may become more adaptive than others (Wilkins, 2002). Adaptive routines replicators have a better advantage and are thus selected and retained by the organisation.

Such a path dependent view is at the core of evolutionary economics and management, where one of the main issues is to identify which structural variations (including variations in routines portfolio) would be retained further within the organisation. In this view, the culture of an organisation may be the result of path-dependent processes since the members of this culture are likely to leave out some aspects by retaining others (Tooby and Cosmides, 1989). A culture is constructed and distributed not only in terms of what is selected but also in terms of what is left out. Lakoff and Johnson (1980) for instance, pointed out that individual members of a culture would not share all the elements of the prevailing cultural stereotype. Nevertheless, evolution occurs at the intra-organisational level because there is both commonality and variation among individual members (Aldrich, 1999). In this context, superstitious learning is both unique and general and the pattern between these opposing poles very much depends on how superstitious beliefs are gradually shared over time.

In this sense, an account of learning relies once again on a path dependent process that is structured around important stop patterns of retention and variation. Some aspects of knowledge (including superstitious knowledge) are retained because their pattern of commonalities and variations give them an advantage in the competition for attention allocation (Hakanson and Ambos, 2010). SL and the routines it impacts thus

persist not because they are useful but because they exhibit unique patterns of generality and difference, which makes them easier to share across the organisation.

This questions the received wisdom with regards to organisational adaptation and fitness theory. Namely, the main assumption of fitness theory is that internal structures and routines of the organisation are adaptive as long as they fit to the constraints of the market environment. Those organisations that do not correspond to these constraints are eliminated over time. Similarly, it is often assumed that "successful" routines have to be replicated as accurately as possible (cf. Williamson, 1975 on memes and routines replication). However, high fidelity routine replication is neither possible nor suitable. The reason for this is that the selection, morphology and reproduction of a "superstition routine" depend on where knowledge is located in the firm and how structured level micro-foundations are distributed (von Krogh and Geilinger, 2014). SL cannot have any impact unless it is explicitly shared and located within the organisation. This suggests that studies documenting the negative effect of SL are over-emphasising its role.

There is a contradiction at the heart of SL in the sense that its impact within the organisation is both deliberate and arbitrary. A closer attention to the role of the individual actors has shown that SL can have an impact only if it is actively shared, located and contextualised within organisational cultures and practices (von Krogh and Geilinger, 2014). However, because of the intentional and active role played by organisational members, SL is shaped around arbitrary ideas and individual preferences (Miller and Taylor, 1995). The emergence of SL can occur at any given level of the organisation. It thus appears that while SL needs the action of individuals in order to have any impact at all, its emergence is random.

(c) Errors and Experience Sources for learning

In some cases, individual failure can have a useful learning value especially when there is an historical investment in the "failed" strategy (Sheperd, 2003). Other studies reveal that failure or near- failure events (e.g. near accidents or simulated accidents) can prompt learning. For instance, pilots or college students, make sense of their failure (or near failure) experiences by questioning why things went wrong and imagining how things could have been done better (Morris and Moore, 2000). Zheng and colleagues (2009) imply that in terms of contingency, learning failure can demonstrate a library effect (i.e. group success enhances individual learning because of a richer experience pool), contrast effect (i.e. a combination of success and failure has a higher learning value as the contrast between the two helps to draw better causal inferences) and the motivation effect (i.e. there are incentives to improve and catch up with successful colleagues).

Such results suggest that research on organisational learning in general, ad SL in particular, should go beyond the simple predictive leaning curve. A predictive learning curve postulates a positive relationship between the amount of experience and performance outcome. For instance, Kim and colleagues (2009) showed that a success experience in a firm setting refers to periods of extraordinary strong performances. At the other end of the spectrum, a recovery experience (in the category of failure experiences) refers to instances where firms are faced with extremely poor performances but are then able to overcome them. Alternatively, it is possible to say that failure is defined as an outcome *below* the expected level while success is defined as an outcome *above* the expected level (Greve, 2003). The main point is that the outcomes of extreme experiences (success and recovery) are by definition, very difficult to interpret. This may easily lead to SL especially in cases where instances of extreme experiences are scarce (March, 1991).

In this sense it is useful to remember evolutionary principles, which stipulate that routines can also be selected in terms of their emotional salience (Heath et al. 2001). To some extent, the same process operates in a firm setting because extreme performances (bad or good) are better remembered. This very salience of extreme

experiences multiplies its impact on the subsequent behaviours of the firm even if the experiences may be harmful or inaccurate (Haunschild and Miner, 1997). In other words, harmful, "superstitious" routines are more likely to be replicated because they are more salient in the first place. This means that any learning derived from success or recovery experiences may give rise to causal ambiguities and thus to bias.

Bias can be avoided if experience and settings are as heterogeneous as possible (Zheng et al., 2014). This implies interesting questions as far as the value of knowledge is concerned: just how much and what type of knowledge is needed in order to derive an appropriate learning path from extreme experiences? In an attempt to answer this question, Kim and colleagues (2009) used a sample of US commercial banks in the analysis of their financial history. The results show that banks facing hazard were more likely to fail if they did not have hazard experiences before. Thus, the issue is not only about the type of experience involved but also about the amount of experience. Flawed experience per se is not enough to cause SL and generate faulty models of organizational action. Instead, flawed experience has a negative impact only when there are a small number of performance outcomes regardless of whether these outcomes are positive or negative (Argote, 2011).

In this context, *Essay I* will focus on the ways in which superstitious learning can expand and consolidate organisational experience.

B) SECTION B – Multimorbidity

Multimorbidity refers to the co-occurrence of two or more medical conditions (Boyd and Fortin, 2010). The healthcare literature tends to explore the complexity typologies involved in multimorbidity care, namely, *case complexity* and *care complexity*. Case complexity refers to situations where interactions between medications and diseases are unpredictable (De Jonge et al. 2001). Namely, the outcomes of interactions between different treatments for patients with multi-morbidity are often unknown (Ritchie, 2007). Moreover, multimorbidity often involves specialists from different domains. As a result, coordinating between different professional domains becomes difficult, especially since the increasing specialisation in healthcare results in the rigidity of professional barriers (Plochg and Klazinga, 2012). In the literature on multimorbidity, this problem is referred to as care complexity.

Both care and case complexity are tied to a specific understanding of what constitutes complexity. Namely, complexity is generally defined in terms of a high number of interrelated and unpredictable interdependencies (Doessing and Bureau, 2015). In multimorbidity care, healthcare practitioners from various domains display a high degree of interdependency. For diabetes cases for instance, nutritionist specialists have to calibrate their care strategies with reference to endocrinologists (Pollack et al., 2013). Alternatively, multimorbidity care may involve a high degree of interdependence between tasks. It is possible to manage a high number of interdependencies if interdependent organisational members and organisational subunits are strongly linked (Hansen, 1999). However, this does not seem to be the case in healthcare settings. Namely, healthcare institutions have difficulties in finding appropriate strategies for tackling the needs related to multimorbidity (Doessing & Burau, 2015).

(a) Systemic Explanations

The literature on multimorbidity tends to explore multimorbidity care according to a systemic framework and complexity theories (cf. Theoretical Framework-CAS

Section 1B). This is a challenge to the evidence-based view, a perspective that is particularly prevalent in internal medicine care (McCrae, 2012). Evidence based medicine relies on measurable factors and concepts and as such, tends to reject any elements that do not relate to scientific and technical knowledge (Knaapen, 2014). By contrast, complexity literature argues that illness, health and multimorbidity patterns result from complex and dynamic interactions between different components of the care system (Cilliers, 2005). Systemic explanations and complexity theory rely on self-organization principles stipulating that the interactions of system actors are more important than the actors themselves. Hence, the path and development of multimorbidity cases can never be fully predicted because they depend on the outcome of interactions between care providers. This has implications for the effectiveness of treatments: the path of an illness is unpredictable and so is the effectiveness of the treatment and of the care program adopted (Juarez, 2011). Thus for instance, it is impossible to apply the same strategy from one patient visit to the next: differing contextual factors or/and illness trajectories have intervened in between.

However, the application of systematic frameworks and complexity theories to multimorbidity care has some problematic aspects. To some extent, assuming a strict equivalency between multimorbidity and complexity may blur the agency of the members of healthcare systems. Namely, if both multimorbidity and complex systems evolve in a way that cannot be predicted, it is not completely clear how individual agents in the care system can have an impact by themselves. What is visible is the *outcome* of collective, shared activities between care team members rather than individual contributions (McKelvey, 1999). As a result, most studies in this field are characterized by a lack of traceability of individual actions (Tuffin, 2016). Agency is tied to a sense of control (i.e. people need to feel that they exert change). If it impossible to control the outcome of actions (as complexity theories suggest), then the agency of individual care system members becomes secondary (McKelvey, 1999).

Moreover, in contrast to complexity theories, multimorbidity does not always produce unpredictable complexity patterns. Namely, interdependencies for some of patterns of

illness are easily predictable both in theory and practice (e.g. diabetes is often associated with heart problems) (Islam et al., 2016). The reason why these patterns are predictable is not only because they are quite common, but also, because healthcare practitioners have integrated such patterns within their care system by creating tools and practices to deal with them (Majchrzak et al., 2007) The question is thus where complexity resides: complexity may be the property of the multimorbidity cases but it may also arise from the interaction between systems members themselves. Indeed on some occasions, relatively easily manageable multimorbidity patterns may be dealt with complex interactions and coordination between systems members (Islam et al., 2016).

(b) Outcome based approaches:

Another possibility is to consider multimorbidity in terms of care outcomes. Namely, complexity in multimorbidity care can be determined by the quality of the medical outcome and by the cost of achieving that outcome (Hardin et al., 2017). There is a contradiction within this outcome-based approach because it is difficult to define an outcome for something that is unpredictable by definition. There are also no real tools that would allow healthcare practitioners to deal with multimorbidity related complexity. For instance, most practical care guidelines are not able to reflect the specificity of older patients with multimorbidity (Guthrie et al., 2012). In fact, no measure of multimorbidity complexity can fully grasp all aspects of care complexity. Grebowski and colleagues (2014) pointed out that the tools available are not designed to address every need. For instance, there is no real attempt to analyze the cross-cultural applicability of such tools.

(c) Mixed expertise teams

The notion that in complex systems, relationships and interactions between agents are more important than the individual knowledge and characteristics of these agents obscures an important aspect of care complexity. Namely, specialists increasingly determine the healthcare setting. This creates knowledge silos with rigid boundaries between knowledge domains (Sheaff et al, 2015). Since multimorbidity care includes

different specialists, findings a common ground for knowledge sharing may be difficult. It is here that the notions of expertise, learning, knowledge and boundaries spanning activities become particularly important. That is to say, members of complex systems usually differ in terms of knowledge, expertise and learning rate. This heterogeneity is especially salient in the initial phases of team creation (Majchrzak et al., 2007). For instance, Vashdi and colleagues (2010) have noted that expert surgeons tend to revert to backward, routinized reasoning only when the clinical problem does not correspond the usual patterns or when hypotheses fail to explain the available data. By contrast, non-experts are able to detect and correct errors only when they receive feedback from external sources.

The issue therefore is how experts can successfully collaborate with non-experts given different knowledge levels and different learning rates. However, the core implication in this stream of literature is that individuals can work and coordinate together even if their knowledge levels and knowledge domains differ. Namely, care teams are able to coordinate in conditions of complexity and uncertainty without ever addressing dependencies between the knowledge domains of their members (Vashdi et al., 2010). Instead, team members tend to diminish differences in knowledge through constant interactions, most notably around shared artifacts and a shared set of practices (Sheaff et al, 2015). This allows them to construct temporal scaffolds to repeatedly share, modify and translate knowledge between each other.

In this context, for both *Essay II* and *Essay III*, the main issue is how healthcare actors with different levels of expertise can coordinate around complexity.

3. Methodology

1) SECTION A - Conceptual Research Method

Conceptual research concerns the observation and analysis of information that is already available (Meredith, 1993). As such, it tends to be used for theory building and the generation of conceptual models. Conceptual models do not explain phenomena but rather, describe or replicate events and processes. Conceptual models are thus a simplified abstraction of reality: they include concepts, constructs and propositions that describe the phenomena under investigation.

Essay I first follows the conceptual framework of *conceptual induction*. Conceptual induction aims to explain the relationships between the phenomena of interest. Namely, the goal is not only to describe the phenomenon accurately, but also to understand how it occurs. In this context, Essay I describes the relationship between autopoiesis, superstitious learning and routine enactment. Namely, I note that autopoiesis theory relies on distinction making in order to interpret the relationship between the organisation and the environment. Organisations reproduce their own routines (that include communication and decisions) according to predefined conditions (i.e. decision premises). I thus note that organisations learn by reproducing their own routines, which in turn, allows these organisations to perceive an alternative external environment. I also note that superstitious learning can alter the perceptions of the environment and thus play a role in the ways in which organisations enact routines. Through the framework of conceptual induction, I was thus able to describe the links between superstitious learning, routines and autopoiesis theory.

However, specifying links between constructs also results in specific predictions of the conceptual framework. This is the domain of *conceptual deduction*. The conceptual deduction framework relies on the relationship between the phenomena, constructs and processes of interest in order to predict the outcomes of these relationships. In *Essay I*, I predict that organisations operating in autopoietic terms will create their own environment for learning by both amplifying and abstracting

their self-produced experiences. Organizations achieve this through superstitious learning, as superstitious learning is able to both simplify and multiply experience.

Finally, both conceptual induction and deduction frameworks generate a theoretical model or meta-frameworks. *Meta-frameworks* include the integration of previous conceptual frameworks in order to define theory boundaries. *Essay I* integrates frameworks concerned with superstitious learning and autopoiesis theory in order to develop a theoretical framework of routine enactment

2) SECTION B - Research Design

Essay II and *Essay III* of this dissertation are based on semi-structured interviews and observations at an infectiology department (ID) at a large Swiss university hospital. Both essays use a single case study design that is particularly suited to qualitative research on complexity coordination (Yin, 2003). The source of the interview data can be traced to the collaborators of the ID department including nurses, junior and senior doctors, study nurses the administration staff. The data collection phase included a total of 43 ID collaborators and lasted from March 2017 to August 2017. An exploratory data collection phase was conducted between August 2015 and November 2016 and included 10 interviews with healthcare experts. The data was then analysed according to systematic inductive procedure for qualitative data. This chapter presents the research context, data access, data collection, data sample and the methodological approaches used in *Essay II* and *Essay III* of this dissertation.

(a) Research Context

Essays II and *III* are based on the data collected in an infectiology diseases department (ID) at a large Swiss university hospital. The aim was to provide an understanding of the perceptions of healthcare practitioners in relation to care and patient related complexity. An ID department is a fruitful setting for complexity-related research for various reasons. First, an ID department includes various specializations across medical domains. As a result, it is possible to explore complexity perceptions from healthcare practitioners with varying degrees of

experience (i.e., junior doctors, nurses and senior physicians). This is relevant for *Essay III* as it explores the difference in complexity perceptions between medical professions. Second, an ID department involves both clinical and non-clinical practitioners. This is particularly relevant for *Essay II*, where the focus of research is on the collaboration between clinical and non-clinical actors on complexity. Finally, the ID department has both in-patient and outpatient structures that allows to explore complexity coordination beyond the medical context.

(b) Data collection and Data Access:

Data collection of the first exploratory phase started in August 2015 and ended in November 2016. It included 10 interviews with healthcare experts on issues related to multimorbidity, care complexity and knowledge creation. The second data collection phase took place place in March 2017 and lasted until August 2017. In collaboration with the clinic director, we scheduled interviews with all available department members, resulting in 31 participants, including 17 nurses, eight junior physicians, and six senior physicians. The interview schedule was refined in various iterations.

(c) Data Sample

The study participants worked all in the ID department. It included nurses, junior doctors, study nurses, senior doctors, administration secretaries and reception secretaries. The complete distribution of the participants can be consulted in the table below:

Table 1 shows the distribution of non-clinical participants:

Administration/ Study Nurses	**Number**
Secretariat	4
Reception	6
Study Nurses	8
Total	18

Table 2 shows the distribution of healthcare providers:

Care Delivery	**Number**
Senior Doctors	7
Nurses	10
Assistant Doctors	8
Total	25

(d) Methodological and Analytical Approaches

Essay II relies on grounded theory. Grounded theory generates inductive strategies for collecting data (Charmaz, 1996). In the initial phase, research starts with individual cases. Data collection and data analysis are simultaneous and both of these research processes are locked in an iterative cycle (i.e. data collection is used as a guide for analysis and vice-versa). Progressively, the researchers are able to develop more abstract conceptual categories in order to outline the relationship within the data and between emerging theoretical constructs. This is particularly relevant for *Essay II* because it does not only aim to explore the lived-in complexity perceptions of healthcare providers (cf. *Essay III*), but also the relationship between different complexity types as well as the environment in which coordination takes place.

Essay III uses a *phenomenological approach* to data collection and analysis. The phenomenological approach focuses on the lived experience of participants (Philips-Pula et al., 2011). In the context of *Essay III*, the focus is thus on the subjective, lived-in perceptions of healthcare providers with respect to patient complexity. Interpretative phenomenological analysis (IPA) was the framework for data collection and data analysis. A central assumption of IPA is that researchers can rely on interpretative processes in order to understand the cognitive frameworks and the experiences of participants.

(e) Data Analysis

Unlike Essay III, *Essay II* includes the analysis of the data provided by healthcare experts. The aim was to determine the factors that either increase or decrease uncertainty. I transcribed extracts from interview recordings, which amounted to 28 pages in total. The raw data was structured by a broad coding scheme derived from the literature. My intent was to outline indicators of relative ignorance such as temporality and intentionality. During the coding process, the doctoral candidate refined the coding scheme in order to obtain more specific general categories.

For the main study phase in the ID department, *Essay II* and *Essay III* relied on 320 pages of single space transcripts data. The data was stored and analysed in NVivo 11 (a qualitative data analysis software licensed by QSR International). This data was analysed according to the systematic inductive approach (Thomas, 2006). Both Essay II and III relied on a preliminary coding frame that was then used to code all transcripts. However, the coding frames concerned different topics. In *Essay II*, the aim of the coding was *(i)* to find relationships between different complexity types and *(ii)* to determine the complexity strategies of clinical vs. non-clinical actors. In *Essay III*, the coding frame was concerned with determining the perceptions of complexity in healthcare providers. Coding frames for *Essay II* and *Essay III* were refined in several rounds with reference to emerging findings as well as the theoretical concepts of the literature.

4. Essay Summaries

1) ESSAY 1:

***(a) Title*:**

The effect of superstitious learning on routine enactment: Towards a framework based on autopoiesis theory

***(b) Authors*:**
Anastassja Sialm (solo contribution)

***(c) Background and Research Question**:*

Organisational learning (OL) has long been dominated by the information processing perspective rooted in the Carnegie School. In this context, learning is identified as a process where inferences from past experiences are encoded into routines (Levitt and March, 1988). Accordingly, superstitious learning (SL) is characterized as a causal misspecification between actions and outcomes (Levinthal and March, 1993). Within the information-processing framework, SL is thus set to disrupt the enactment of routines because it distorts organisational perceptions of causal relationships in the environment.

By contrast, the autopoiesis theory perspective has not fully determined the role of superstitious learning in routine enactment and reproduction. Autopoeisis refers to systems that sustain themselves by reproducing their own components (Maturana, 2002). In an autopoiesis perspective, organisations are thus composed of decisions and routines that are continuously reproduced so that an organization can distinguish itself from its environment (Luhmann, 1990). In this context, both learning and superstitious learning depend on the reproduction of decisions from moment to moment. Routines are thus not enacted in relation to an external environment. Instead, routines are enacted according to the internal rules and structure arrangements of the organisation.

Essay I thus aims to explore the role of superstitious learning in routine enactment within an autopoiesis perspective. Namely, superstitious learning has some characteristics (such as the generation of excessive causal patterns) that can help organizations to self-produce their own environments from which they could learn and to which they can adapt and enact their routines accordingly.

(d) Publication Status:

Submission plans towards *Academy of Management Review*.

(e) Methodology:

Conceptual Research method

(f) Results:

Essay I proposes a new theoretical framework explaining how organisations can use both autopoietic principles and superstitious learning in order to construct an amplified, self-produced environment where routines can be safely enacted and matched to self-generated opportunities. The model includes four steps:

- Superstitious learning helps to enact routines in the organization by enabling the organisation to produce its own environment. Both superstitious learning and autopoietic processes of decisions reproduction rely on *self-fulfilling prophecies* in order to consolidate each other. Namely, the organisation will focus on those features of the (observed) environment that will reinforce their enacted routines. "Superstitious" routines are thus the ones that will be reproduced further.

- SL contributes to the consolidation of autopoietic processes in organisations by activating the process of autonomous cooperation and control (ACC) between the organization's components. ACC specifies that routines and decisions can be reproduced in any conceivable order (Hülsmann et al., 2008). This independence results in a state of heterarchy. Since superstitious learning

is heterarchic as well, it amplifies heterarchic autopoietic processes of routines reproduction.

- Superstitious learning helps the organisation to enact routines by producing simplified and abstracted observations of the environment through a process of disconfirmation. Through disconfirmation processes (Section 3.1), routines are compared and contrasted to constructed "external opportunities" by discarding their irrelevant attributes. It thus becomes possible to create an abstracted, simplified environment with high-level generalizable relations between the organization and the environment.

- Superstitious learning helps to enact routines of an organisation by contrasting routine enactment in the amplified, self-created environment of the organisation with the perceived opportunities to behave (act) in the external environment of other systems. Through the conflation of categories of observations, SL opens "autopoietic" organisations to different modes of operation and communication (e.g. communication of presence or absence of participants in interaction systems).

***(g) Implications and Contributions**:*

- In traditional organisational learning literature, superstitious learning is considered as causality error that compromises organisational actions and survival in the environment. However, the model shows that superstitious learning has a more constructive role. The autopoietic theory provides a more nuanced role for SL because it sees self-organisation (rather than a strict adherence to external contingencies) as a key dimension for learning and change. SL thus finally acquires a functional and operational role for organisations because its impact depends on internal organisational processes rather than on external arrangements.

- The notion of self-created autopoietic environments suggests that the ultimate purpose for organisations is not adaptation but survival.

2) ESSAY 2:

(a) Title:

Finding a Black Cat in a Dark Room: Dynamic Self-Organizing Perceptions of Uncertainty and Complexity in Multimorbidity Care

(b) Authors:

Anastassja Sialm (first author)
Shiko Ben-Menahem PhD

(c) Background and Research Question*:*

Multimorbidity (MM) raises important challenges for the coordination and provision of care. It involves a complex pattern of interdependencies between conditions, medications, and healthcare systems. In this context, complexity in multimorbidity care is often seen in terms of complex adaptive systems (CAS). However, while the CAS framework has provided insights on how multidisciplinary teams operate, there are concerns that it ignores individual the intentionality of team members. Moreover, complexity literature in healthcare does not fully differentiate between complexity and uncertainty. Finally, the literature on collaboration between clinical and non-clinical actors is relatively scarce.

Essay II thus aims to understand how non-clinical actors collaborate with healthcare providers in multimorbidity care. In so doing, it differentiates uncertainty from complexity by specifying that uncertainty includes a relative ignorance of interdependencies between care measures. *Essay II* also explores how non-clinical actors rely on stigmergy principles in order to provide a coordination environment for care providers.

(d) Publication Status:

Submission plans towards *Social Science & Medicine*

(e) Methodology:

The study relied on a single site case study design. The analysis and data collection was made according to the principles of Grounded Theory (qualitative). Data consisted of in-depth open-ended interviews.

(f) Results:

- Non-clinical healthcare actors provide both stable and unstable conditions that allow healthcare providers to manage complexity and uncertainty in multimorbidity care. Stable conditions are related to predefined parameters of registration and document production while unstable conditions are related to an unbalance between the contents of administrative documents and the format according to which such documents are produced.

- Non-clinical healthcare actors determine the activation zones for workflow complexity. This gives care providers the possibility to trace information even if constant attrition obscures this information from the records.

- Care providers build on the feedback provided by non-clinical doctors in order to adjust their approach to care delivery complexity. Their approaches include empirical ad-hoc strategies and compensation effect management.

(g) Implications and Contributions*:*

Unlike complexity, uncertainty in multimorbidity care can be modulated in individual terms, according to the medical profession concerned. This corresponds to recent literature on uncertainty where individual modulate the degree of uncertainty they encounter.

3) ESSAY 3:

(a) Title:

Health Care Providers' Experience and Perceptions of Patient Complexity: An Observation Study in HIV Outpatient Clinical Practice

(b) Authors:

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Anastassja Sialm
Anna Hachfeld MD (Department of Infectious Diseases, Bern University Hospital)
Andri Rauch MD (Department of Infectious Diseases, Bern University Hospital)
Georg von Krogh PhD
Hansjakob Furrer MD (Department of Infectious Diseases, Bern University Hospital)

***(c) Background and Research Question**:*

Patient complexity is an increasingly popular concept in clinical practice, policy debates and medical research. Yet the literature lacks a clear definition of its meaning and drivers from the health provider's perspective. In this context, the aim of *Essay III* is to develop an empirically grounded knowledge on how complexity-contributing factors of HIV patients translate into health care providers perceptions of care complexity.

In order to understand under what conditions case complexity translates into perceived care complexity, *Essay III* differentiates case complexity from care complexity. Namely, case complexity relates to patient-related factors while care complexity relates to medical care.

(d) Publication Status:

Submitted to *BMJ Open* on 08.03.2021

(e) Methodology:

The study relied on a single site case study design. The analysis and data collection was made according to the principles of Interpretative Phenomenological Analysis (qualitative). Data consisted of in-depth open-ended interviews.

(f) Results:

- *Essay III* identified case two complexity drivers namely, (*i*) multimorbidity and (*ii*) mental health. Complexity moderators at the patient level included demographics, objectives and behaviours as well as knowledge and personal resources. At the care provider level, complexity moderators included experience, expertise and time.

- Case complexity drivers and a set of complexity moderators at the patient level, care provider level, and care context level jointly determined care providers' perceived controllability. Providers' perceived controllability, in turn, was a key driver of perceived care complexity.

(g) Implications and Contributions*:*

- -The study moves from objective complexity-contributing factors in patient's medical health state to a broader, holistic framework including non-medical factors.

- -The study addresses patient complexity as a combination of patient characteristics and practitioner experience.

- -The findings are particularly relevant for learning programs and curricula at the post-graduate level. This applies particularly to geriatrics and general internal medicine, in which skills for managing care for older multimorbid patients are necessary.

5. Contributions and Limitations

The general focus of this dissertation was to harness the potential of faulty, incomplete knowledge for organisational persistence and survival. While learning is considered to be an existential need for the organisation, there is little exploration of the forms of organisational existence. For instance, there is a vast amount of research on the "ideal" structure organisations need for their survival, but there is little consideration about why organisations have to survive in the first place. This focus on organisational survival obscures the fact that long lasting organisations are not mandatory phenomena. For instance, the market environment is populated by temporary organisations whose strategies and structures are specially adapted to a short life span (Asheim, 2002). Sometimes, it is better to burn bright for a short time than to not burn at all. The question is thus not only why organisations learn (cf. Introduction Section) but also why organisations exist in the first place.

Well-established theories of learning (such as the Carnegie School perspective outlined in *Essay I*) have a straightforward answer to this question. Organisations exist in order to learn, acquire and generate new knowledge (Levitt and March, 1988). Hence, routine have to be constantly adapted and renewed (March, 1991). Organisations exist to reach the peak of the fitness landscape and achieve the highest fitness value through constant changes in their form and structure (Levinthal, 1997).

However, this constant aspiration to excellence is not always supported by practice. There are various cases where maladaptive organisations, with out-dated inefficient structures and knowledge stickiness issues still manage to hold for some time (Poulis and Poulis, 2016). For instance, a family firm may survive over generations not because it constantly adapted to the opportunities of the environment but because of chance (De Rond and Thietaart, 2007) or phronesis (Tsoukas and Cummings, 1997).

The present dissertation may help to understand such contradictions. As *Essay I* suggests, the environment of an organisation is amorphous (Riegler, 2006). That is to say, the environment contains such an enormous amount of data that any causal relationship is potentially possible. In such a context, an organisation has to make a choice about the knowledge and routine it wants to reproduce. According to autopoiesis theory, organisations exist because they reproduce their internal

knowledge and routines and because they make a choice in the ways in which they differentiate themselves from an alternative environment. In this sense, organisations are "immortal" as long as they maintain their structure and identity (e.g. a bicycles producing plant ceases to be a bicycles producing plant as soon as it begins to produce spare parts for cars). However, *Essay I* goes further and argues that superstitious learning determines the conditions under which such choices are made by generating antithetic comparisons.

Thus, what is crucial in knowledge reproduction and organisational survival is not the choice an organisation makes but rather the conditions for marking such a choice. Both Essay II and Essay III follow this line of enquiry in relation to complexity in multimorbidity care. *Essay II* documents how non-clinical actors are able to provide coordination and workflow environment for clinical actors, despite having only a surface knowledge of medical and care related matters. Once again, the central issue is that non-clinical actors provide the conditions necessary for making a choice under the auspices of non-linear, self-organising theories. *Essay III* extends this notion by exploring how care providers modulate their perceptions of controllability in order to structure their response to care complexity.

While this dissertation provides a useful framework for understanding knowledge reproduction processes, it displays limitations in some areas. Essay II would have benefited from a more in-depth exploration of the concept of uncertainty. However, its description of the links between uncertainty and relative ignorance can be a potentially fruitful area of research. This is particularly relevant for research where ignorance is a potentially useful commodity (e.g. Rayner, 2012). In its argumentation, *Essay I* does not always differentiate between the organisation and the system. Nevertheless, I believe that knowledge reproduction through inert historical facts and strategic ignorance may be of interest for those researchers who are interested in the knowledge creation processes.

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Part II Essays

ESSAY 1 :

The effect of superstitious learning on routine enactment:
Towards a framework based on autopoiesis theory

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ABSTRACT:
Research on superstitious learning (SL) has been long dominated by the information processing approach rooted in the Carnegie school. As a result, SL is generally considered erroneous as it distorts routine enactment and an effective organisational response to the environment. This paper challenges such an approach by outlining the functional and operational benefits of SL for routine enactment. To develop a novel theoretical model, I draw on a body of scholarly work on autopoietic systems. Integrating autopoietic principles of distinction making with SL in routine enactment, I argue that SL may generate representations of the environment that facilitate the anticipation of environmental characteristics and changes. Routine enactment depends on the ability of the organisation to create its own environment with self-generated rules of behaviour.

I) INTRODUCTION

Superstitious learning (SL) has long been considered an aberration of organisational learning (OL) (Levinthal, 1997). Authors, who belong to the Carnegie School (CS),

have tended to define SL as a way to conceptualise organisational learning (Levitt and March, 1988). Both organisational and superstitious learning are defined in terms of regular patterns of actions and rules which, once they agglomerate into routines, shape organisational behaviour (Gavetti, et al., 2007). OL is a process of encoding inferences from past experiences into routines (Levitt and March, 1988), while SL is characterised as a causal misspecification between actions and outcomes (Levinthal and March, 1993).

In this context, routine enactment (which refers to the performance of routines (Rerup and Feldman, 2011) connects inputs (from actions) with outputs (the feedback from the environment) (Feldman and Pentland, 2003). Since SL misrepresents action-outcome links, it distorts the representations of situations at hand, which, in turn, causes faulty decisions by the organisations, and disrupts the enactment of routines (Heimeriks, 2010). A less negative view held by some authors is that errors, biases and superstitious beliefs as potentially valuable organisational resources (Rumelhart et al., 1986). For instance, superstitious beliefs may help organisations to reach decisions in uncertain, novel or ambiguous situations (Tsang, 2004).

Conversely, the theory of autopoietic systems has yet to clearly determine the role played by superstitious learning for organisations and routine enactment. According to its initial definition, autopoiesis refers to systems that sustain themselves by reproducing their own components, drawing on certain types of inputs such as energy from their environment (Maturana, 2002). A system is thus both open to external perturbations (as it depends on external energy) and operationally closed (everything that the system produces originates within the system in reference to itself) (von Krogh et al., 1994a). Within this logic, there is no need for superstitious learning per se because no causal relationship generated by the system can be directly checked against the environment.

This turns the focus to system components and more specifically routines. Routines are crucial components of the system because they are act as vessels through which organizational knowledge is shared, modified and communicated in the organisation (Jashapara, 2004). For the Carnegie School, routines include sequences of actions,

behaviours and response programs that are either retained or discarded according to environmental feedback (March, 1991). Conversely, the autopoietic theory argues that routines contain decisions and communications that are reproduced internally (Luhmann, 1990). That is to say, an organization reproduces decisions in order to distinguish itself from the environment. Through this reproduction of decisions, the organization changes the medium in which it operates (Koskinen, 2013). Because of this change, some decisions are reproduced more frequently than others and become routines. These routines in turn, frame the reproduction of further decisions (Luhmannm 1990). Hence, the reproduction of routines becomes an essential part of organizational culture (Seidl, 2003)

However, what enables the system's survival is that its components (such as routines and causal relationships) are continuously reproduced, not the components themselves (Seidl, 2004; Cooren, F., & Seidl, 2020). In this sense, drawing clear lines between organisational learning and superstitious learning becomes more complicated, if not moot. All learning is rooted in the system's own reproduction. Yet, the sociologist Niklas Luhmann's reworked the theory of autopoiesis to make it better suited to describe organizations and other social systems (Luhmann, 1986). This may provide a functional role to SL within organisations.

In an autopoiesis perspective, organisations are composed of decisions that are continuously reproduced so that an organization can distinguish itself from its environment (Luhmann, 1990). Unlike in Maturana's work, the reproductions of elements (such as routines) of the system are not stable. Instead system elements are momentary events that disappear as soon as they have unfolded (Blackman and Henderson, 2004). For Luhmann, the system thus learns by permanently reproducing its components (such as routines) through internal knowledge-creation processes (e.g. distinctions between the system and the environment) (Luhmann, 1995). Namely, OL and SL occur once the environment becomes observable to the organization through distinction.

This means that learning has to connect to previous learning in order to ensure the survival of the organisation as a whole (Blaschke, 2010). New knowledge refers both to past and future knowledge because an organization cannot distinguish itself from

its environment without reference to past and future learning (Seidl, 2004). In this context, both learning and superstitious learning are momentary, because they depend on the reproduction of decisions from moment to moment. Routines are thus continuously enacted, not in relation to external environmental structures, but rather as a means for organizations to distinguish themselves from their environment, and in so doing allow organisations to "observe themselves" relative to their environment (Blaschke, 2008).

In an autopoiesis perspective, some properties of superstitious learning such as the generation of excessive patterns, standardized cause-effect links and recursive causality may offer opportunities that "standard" organisational learning does not (Gosselin and Schyns, 2003). Because of an organization's relation to the external environment, superstitious learning may impact how organisations observe and define themselves (Riegler, 2007). In this paper, I will further elaborate on these ideas, and propose a novel theoretical framework of the routine enactment based on superstitious learning and autopoietic theory. I intend to show that SL may allow organisations to self-produce their own environments from which they could learn and to which they adapt and enact their routines accordingly.

In the following, I first outline how the Carnegie School on the one hand, and the autopoiesis theory on the other, define organisational learning, superstitious learning and routine enactment. The Carnegie School follows an *information processing* approach where SL is defined in terms of inputs-outputs differentiation and external feedback. By contrast, the autopoietic theory relies on a *distinction processing* approach and thus interprets SL in terms of operational closure and anticipated decision premises. I discuss how these two contrasting interpretative frameworks define SL's role in the organization. Next, I outline the ways in which SL and autopoietic principles affect routine enactment. For the Carnegie School, routines are enacted in close relation to external environments (Levintahl and Posen, 2007). In autopoiesis theory routines are enacted in relation to a self-generated environment (Jonassen, 1999).

Finally, I propose a new theoretical framework explaining how organisations can use both autopoietic principles and SL in order to construct an amplified, self-produced

environment where routines can be safely enacted and matched to self-generated opportunities. A self-produced environment can then be used as an experimental ground, a probing stone for enacting routines in the "real" world. The goal is to show how mutual interaction between superstitious learning and autopoietic characteristics of organizations provide a potential for organizational change, survival and development.

II) THEORETICAL BACKGROUND

2.1 Framing Superstitious Learning: Information Processing vs. Distinction Making

Learning becomes superstitious when the connections between actions and outcomes are misspecified (Levitt and March, 1988). The subjective experience of superstitious learning is so compelling that such misspecifications are not noticed by the learner. A recurrent finding in the organizational learning literature is a persistence of superstitious learning in organisations (Beck and Forstmeier, 2007). For scholars who write in the Carnegie School tradition, superstitious learning persists because an organisation in closely related to the environment in which it exists. Namely, organizations process information from and about their environments, and their learning about these environments consists of an encoding of inferences from past experiences into routines that shape behaviours (Levitt and March, 1988).

In Carnegie School terms, organizational and superstitious learning both depend on *(i)* a *separation between inputs and output* and *(ii)* on *feedback from the external environment*. Accordingly, SL distorts the perception of changes and processes in the external environment by identifying causal relationships where there are none (Beck and Forstmeier, 2007). For example, a market is served by two firms A and B producing differentiated but substitutable products. Introducing a new feature on a product manufactured by firm A occurs simultaneously with an increase in demand for the product in the market. Superstitious learning at firm A would be present if the firm infers that the new feature causes a demand increase, while the “real” reason is a supply shortage due to manufacturing constraints by firm B.

Conversely, with autopoiesis theory, *distinction making* gives both a functional and operational role to superstitious learning. Because an organization has no direct access to the "real" environment, it is forced to observe and construct this environment by making distinctions (Luhmann, 1990). The core distinction is the one between the organization and its environment. For example, a firm would distinguish between profitable vs. non-profitable ventures, its business vs. other businesses, its product vs. others products. Myriads of such distinctions are made at any moment in an organization, making it a system that can produce and reproduce itself and maintain an identity relative to its environment.

In order to maintain the core distinction and identity, the organization must continuously reproduce itself through its own components. Hence, an organisation is composed of decision and communications that are recursively reproduced by the organisation (Luhmann, 1990). In effect, SL does not essentially distort the representation of changes in the external environment, since this environment is neither directly accessible nor visible for the organization. Moreover, since an autopoietic system selects and distinguishes elements such as communications and decisions from its own processes retrospectively, it becomes less vulnerable to the linear causal relationships produced by SL (Cheong et al., 2014).

Superstitious learning thus exerts a possible impact in two domains: the reproduction of organisational components (i.e. decisions and communications) and the distinction between the organisation and the environment. Namely, an organisation is a type of social system and its components are thus a variety of communications, namely decisions (Seidl, 2004). Organisations reproduce themselves through decisions while the self-reproduction of these decisions generates distinction, selection and eventually organisational learning (von Krogh et al., 1994b).

A decision represents the potential for an alternative: a decision to buy milk instead of water suggests that water could have been chosen instead. Organisational learning occurs when decisions (and the associated routines evoked in making those decisions) are communicated and reproduced within the organisation (i.e. an organisation learns

by making distinction through decisions) (Blackman and Henderson, 2004; von Krogh et al., 1994; von Krogh and Roos, 1995).

However, there are always viable alternatives for every decision taken (Seidl, 2004). Hence, the more a decision is communicated, the more likely an alternative decision will gain legitimacy at the expense of the one that has been selected. In Carnegie School terms, SL acts as a ‘’spoiler’’: it will favour decisions based on non-existing causal relationships while delegitimising the decision that has been taken (Zollo, 2009).

Conversely, adopting an autopoesis theory view, both OL and SL have the potential to distort decisions since both types of learning originate from the closure and the core distinction of organisation. Organisations are doubly closed through (i) their *modes of operations* and (ii) their *anticipatory decision premises*. In the next sections, we will show that SL can both help organizations to establish distinction and attenuate organisational closure. *Table 1* summarizes and contrasts perspective on learning on various dimensions for both the Carnegie School and Autopoiesis theory.

Table 1: Carnegie School vs. Autopoiesis theory Summary

	Organisational Learning	**SL definition & impact**	**Routines**	**Relationship with the environment**
CARNEGIE SCHOOL INPUT-OUTPUT DIFFERENTIATION FEEDBACK ORIENTED	-Routine based and Schema oriented -Schema contain representations of external causal relationships. -Causal and Linear (action-outcome link) -Anchored in past experiences -OL is the result of a*ccumulated experience*, defective actions are discarded over time while effective actions are retained. -Target-oriented (actual *v*s. desired outcome comparison) -Path-dependent -Knowledge is selected by the organisation in reaction to the perceived changes in the environment.	-SL is a causal misspecification between actions and outcomes. -Impact on routine enactment : SL distorts the perception and retention of routines . -Produces causal relationships which don't exist. - Connections between the organisational action and environmental response have no real basis. -Overspecification and overproduction of causal patterns (causal bias) -SL is falsifiable and can be checked against real relationships in the environment.	- Consist of routinized action sequences triggered by stimuli from the environment. Are adaptive to the characteristics of the stimulus (e.g. location, duration etc.) - Include *(a)* a sequence of behaviours/response programs and *(b)* programs which select the appropriate responses. -Enacted according to the principle of bounded rationality. Grounded in procedural knowledge and past experience. -Act as stores of organisational memory. - Habit/feedback driven.	-Outside-in perspective (i.e. the environment is the active agent while organisations just respond to external perturbations) -Complete match with external environmental conditions -Articulated around existing causal relationships in the environment. -Causal relationships in the environment are *fixed in time*
AUTOPOIETIC THEORY OPERATIONAL CLOSURE SELF	-Organisations learn through the reproduction of their own components and boundaries -Is self-referential and does not need direct external	-Happens through the reproduction of organisational elements (e.g. routines) -Is created through reference to anticipated internal processes in the organisation.	-Routines are reproduced in self-referential way within the organisation that in turn reproduces the organisation's boundary. -Arise of the structural self-	-Closed to the environment. Perceives the environment through own boundaries. - Autopoietic Unity and Unspecific Environment (semiosis: signs from then environment are interpreted through the unity of the autopoietic system and in terms of the production and

PRODUCED ANTICIPATORY DECISION PREMISES	inputs, experience and environmental feedback -Not falsifiable since no external reference. -Generates self referential and history dependent knowledge - Schema contain actions sequences (self produced by the organisation) -Schema produce information (rather than processing it)	-Information producing strategy: Creates overspecifaction and additional patterns of anticipations of the environment. -Not falsifiable	reference and self-reproduction with the system boundaries. Act as amplifiers of choice. -Routine Enactment reproduces the distinction between (1) organisation and structure and (2) observation and experience. - Enacted according to an anticipation-based, constructivist logic - Embed tacit organisational knowledge through their physical and cybernetic structures.	reproduction of this unity.) -Structural determinism between elements: co-evolutes and co-changes in relation to the structuralism determinisms of the systems operating in it.

2.1.1) Operational Closure vs. Input-Output differentiation in organisational and superstitious learning

Many authors in the Carnegie School assume that OL occurs because inputs (i.e. actions) and outputs (i.e. the representations of these actions) to the system are *separate* and different entities (Eggers and Kaplan, 2013; Simon, 1952). This separation is expressed in the ways in which representations are conceptualized. Namely, representations arise when observers make inferences on the external relationships in the environment (i.e. inputs) (Clancey, 1997). Representations are encoded in routines, which then act as a context for managerial interpretations of the environment **(**Rerup et al., 2011). At the organisational level, routines affect subsequent representations by guiding further action and shifting the attention of organisational members (Eisenhardt and Martin, 2000).

In autopoiesis theory terms, organizations are operationally closed because they make distinctions about what should and should not be ignored through internally produced

decisions (Seidl, 2004). The implications of closure pertaining to the reproduction of decisions and communications in the organisations are crucial for organisational and superstitious learning. First, organisations autonomously determine what they learn. In contrast to the Carnegie School, there is no representation of the external world per se. Instead representations in autopoietic systems contain anticipated meanings, communications and routines that are generated internally by the organization (Doolittle, 2014).

Second, organizational closure also means that organisations have no complete control over what they learn. Organisations are closed to the environment and as such, have only one internal mode of operation for reproducing decisions at their disposal (Seidl, 2004). The implication is that organizations do not completely control how and what they learn. An organisation cannot distance itself from its own observation of the environment, which means it is dependent on the autonomous reproduction of its routines and decisions (Luhmann, 1991; Krogh et al., 1994).

This discussion reveals a fundamental difference regarding the view of SL between the Carnegie School and the autopoietic theory. The Carnegie School argument indicates that organisations may control their learning processes through the representation of feedback and encoding of routines (Feldman and Pentland, 2003). As a result, SL is seen as a misattribution, alteration or loss of control. For instance, faulty cause and effect relationships (and thus SL) are likely to occur in situations where the frequency and the occurrence of the desired outcomes are outside individual control (Blanco et al., 2011).

For autopoiesis theory in contrast, SL does not pose a problem of control loss, but one of self-description: organisations distinguish themselves from their own processes and from the environment through self-observation. SL becomes a "simplification tool'' through which organizations thus describe themselves: it provides a simple distinction between behaviour and outcome in causal terms (Risen, 2016). In this context, SL is a strategy of producing patterns of communication and decisions that allow organizations to make distinctions in opposition to an ''inert'' environment where any causal patterns and structures are inherent (Riegler, 2006).

The Carnegie School's differentiation between the inputs and outputs is thus replaced by a distinction between what is inside of the organization and what it outside of it (Luhmann, 1991). Within the autopoiesis theory, perturbations allow organizations to react to external changes (von Krogh et al., 1994). The perturbations brought in by SL have another function: they open organizations to modes of self-production with elements other than decisions. This is because SL is not only a "causal attribution mistake" but also a "category mistake" where the properties of one ontological category are used to describe another ontological category. Namely, children have a grasp of core categories for different ontologies (such as physics). For instance, they know that balls can have an impact on each other only when they touch (Welman and Gelmanm 1992). SL occurs when properties of one domain are conflated across other ontological categories (Lindeman and Aarnio, 2006). For instance, mental attributes are attributed to physical objects or vice versa (e.g. the belief of psychokinesis where thoughts touch objects).

Hence, by bringing "category mistakes" into the organization, SL can enforce a categorical change in the modes in which an organization operates. As we have seen, organizations cannot distance themselves from their observation of the environment because they only have one internal mode of producing decisions (Seidl, 2004). The ''category mistake'' between communication and decisional modes (e.g. it is communications that make distinctions between the organisation and the environment, rather than decisions) may allow the organization to "see" and act upon systems and modes of communication other than their own.

2.1.2) Anticpatory Decision Premises vs. Feedback in organisational and superstitious learning

A crucial characteristic of studies within the Carnegie School is its feedback-centred and routine-based account of organisational learning (Clegg et al., 2003). Behaviours are based on routines as organisations adapt to specific situations. Routines, in turn, are enacted and devised on the basis of past experiences. For instance, actions with perceived positive outcomes will be retained while perceived negative outcomes will be rejected. (Argote and Greve, 2007). Behaviours, actions and routines are modified

depending on the relation between the outcomes observed and aspirations within the organization (Eggers and Kaplan, 2013).

Here the conceptualisation of SL follows the same logic of feedback. SL is a way to find patterns, rules and meaning in order to manage the constant inflow of external information (Risen, 2016; Levinthal and March, 1993). The causal SL related patterns are interpreted as the unavoidable consequence of the limits in information processing. For instance, the constraints on the cognitive system lead to misinterpretation of experiences, which in turn, leads to SL bias (Eggers and Kaplan, 2013).

Adopting an autopoiesis perspective, organizations are not prone to receive feedback from the external environment on their behavior, because they remain closed through the self-production of decisions and communication. In this context, it is key to discuss anticipatory decision premises. Decision premises are preconditions that generate decision situations (Seidl, 2004). For instance, educational programs generate educational decisions rather than decisions about telecommunications infrastructure or healthcare. Because organizations have no direct relationships with the environment as a source of feedback, decision premises act as substitutes for external and environmental orientation (Kenny, 1989).

Decision premises contain routines that serve as programs for further decisions (Blaschke, 2008), meaning that any decision of the organization is to some extent self-referential. Decision premises in this manner create decisions that, in turn, become decision premises and so on (Luhmann, 1991). Self-referentiality is a crucial part of the autopoietic system, and is the basis of the organization's observation of itself in its environment (von Krogh et al., 2004). Organizations can anticipate external input (for example material and energy flows) through decision premises because these premises remain self-referential.

Within this logic, both OL and SL depend on the self-reference of decision premises and the organization's ability to cope with uncertainty (Luhmann, 1990, Seidl, 2004). Based on incomplete information, every decision (and thus learning based on this decision) is uncertain. However, choosing one alternative over the other

eliminates any uncertainty or incompleteness of the information pertaining to the original decision situation. Both learning and superstitious learning thus depend on the *connections* between decisions where any potential ambiguity is resolved through a specific decision being made.

SL thus has an important role in absorbing uncertainty in the organization: it favors a decision alternative by either obscuring relevant information or producing information that is not there (Risen, 2016). There is no need to directly deal with uncertainty as it is ‘’absorbed’’ in the network of decisions that constitutes the organization. It is not that uncertainty of information disappears per se, - rather it is no longer visible within the network of decisions (Seidl, 2004).

Both OL and SL thus operate in relation to the self-reference of decision premises and their associated routines. Decisions later influence their decision premises not only in terms of immediate subsequent decisions made, but also in terms of decisions taken much later on (Luhmann, 1991). Gradually, SL opens important opportunities for the ways in which organizations can observe themselves because its impact on organizations is not immediate. For instance, Hülsmann and colleagues (2008) show that SL and “biased” categorizations do not occur consistently at every level of the firm, but rather emerge in random ways with no clearly identifiable feedback.

2.2 The impact of Superstitious Learning on Routine Enactment: Information Processing vs. Distinction Making

In the previous section, I outlined that the Carnegie School interprets an organization’s relationship to the environment in terms of information processing. The organization processes external input, generates representations of these inputs and produces routines according to these representations. In autopoiesis theory, organizations construct and observe the environment by making distinctions between themselves and the environment that they inhabit.

Thus, information processing and distinction making frameworks each have different ways of specifying how and where routines are matched and enacted according to

changes in the environment. The information-processing framework of the Carnegie School specifies that organizations are tightly coupled to their environment and enact routines accordingly. Namely, connections to the external environment are strong and thus, every change of the environment directly affects the organization itself (Hernes and Bakken, 2003). This responsiveness to external changes is reinforced by the strong interdependence between organisational components (such as routines).

Conversely, the decision-making framework of the autopoiesis theory argues that organizations are structurally coupled to the environment. This means that routines are enacted independently of any direct external input (cf. organizational closure at Section 2.1.1.). For Luhmann (1991), structural coupling refers to the relation between systems. Namely, different systems cannot share their communications, but they can nevertheless react to their respective self-production processes because their modes of self-production are adjusted to each other. The system can thus indirectly react to environmental events because self-production processes are structurally adjusted to those in the environment. Thus, for instance, a sale contract structurally binds legal and economic systems together: in the former case, it constitutes a legal communication and decision, while in the latter case, these are economic (Seidl, 2004).

2.2.1 Routine Enactment as a Simplification of Experience vs. Routine Enactment as Amplification and Abstraction of Experience

The difference between Carnegie School and autopoietic theory is that the former enacts routines by simplifying past experiences and relationships within the environment while the latter enacts routines by creating environments. For the Carnegie School, routine enactment is articulated in terms of its differentiation between actions and outcomes. This is because, routines and organisational structures are connected to each other through path dependence and abstracted, de-contextualised situations (Pentland and Feldman, 2005). SL reinforces such abstraction between action and outcomes by simplifying experience in learning. For instance, SL tends to merge cause and effects together and imposes simple causal frameworks (Seel, 2012).

SL can thus influence the enactment of routines only when routines are encoded from the particularity of the situation they first appeared in (Becker et al., 2005). Since such encoding is necessary for organisational learning to occur (incoming information is categorized and simplified through representations), SL is not simply a by-product of learning, but an unavoidable consequence of it. SL thus encodes and simplifies organisational experience and subsequent routine enactment because the limitations in processing new information do not allow organizations to learn from heterogeneous experience (Kim and Miner, 2007).

Thus, for the Carnegie School, organisations need a background of shared and abstracted values in order to enact routines (Puranam and Swamy, 2016). As a result, organisations have to encode the outcomes of their actions into simple categories and allocate attention to salient issues that may be subject to SL biases (Seel, 2012). SL induced routines are thus enacted in terms of generalised, abstracted properties which similarly apply across situations (Kolb, 2014). SL thus provides a biased contextualization for routine enactment (Stańczyk-Hugiet et al., 2017). For instance, the integration of typically western super departments in China's administrative system failed because SL enforced a biased contextualisation where the symbolical relevance of a reform out-weighted its practical purpose (Tsang, 2013). SL thus inhibits the enactment of routines (in this case administrative reforms) within the market environment.

In contrast, within an autopoiesis perspective, SL contributes to the reproduction of conditions that allow organizations to generate their own environment. In order to achieve this, organizations have to amplify and over-extend their structures for routine enactment. In order to understand why, we have to examine the role of structural coupling and anticipatory decision premises in organizations. Structural coupling means that there are environmental constraints on the range of possible structures that systems can use for their autopoiesis (Valentinov, 2015). Namely, the structure of an autopoietic system allows the system to react to certain environmental events at the expense of others. Luhmann (1995) notes that this structural selectivity is what protects the system against environmental complexity. However, such structural constraints also ensure that the system’s complexity remains inferior to the complexity in the environment (Valentinov, 2015). As a result, the

system becomes less sensitive to external perturbations and thus, less able to notice external changes.

For organization, these structural constraints are identified as decision premises. I noted that organizations could not escape the decisional modes of operation because decisions are reproduced recursively (cf. Section 2.1.2). SL can help organizations to circumvent their decisional and structural constraints by constructing temporary substitute structures for cognitive niches in the environment (Bertolotti, 2016). For humans, niches refer to the mediating structures between cognition and self-generated anticipations of the external world. For instance, writing is an example of extended cognition because it extends our minds beyond our brains and allows us to perform cognitive tasks that would have been impossible otherwise (Clark and Chalmers, 1998). In this context, written materials (such as a code of laws) become cognitive niches that aid thinking: they give prescriptions and guidelines that reduce environmental uncertainty and what to expect from others (Bertolotti, 2016).

However, such cognitive niches are not always available. In such cases, superstitious learning and superstitious practices generate crude but operable cognitive structures in the environment through superstitious props (e.g. rituals, items etc.) (Bertolotti, 2016). SL thus enables routine enactment by structuring an anticipated experience of the environment. As I noted in Section 2.1.2, decision premises act as substitutes for external and environmental orientation. However, this means that organizations are limited in their ability to respond to environmental changes because they are limited by their structure. SL and its "ready-to-wear" structures in the environment can temporarily replace decision premises as environmental orientation for organizations. This in turn "frees'' organizations from the constraints of their structure.

"Superstitious" routine enactment links closed systems to the observed environment and thus becomes a source of perturbations within the system. These perturbations, in turn, prompt a response from the system: it produces excessive patterns and over-specification of relationships between actions and outcomes, including non-existing causal correlations (Shermer, 2008). Namely, organizations have the ability to produce excessive variety in relation to the environment (i.e. SL creates more complexity than the amount of complexity present in the environment) (McKelvey,

1999; Bertolotti, 2016). If SL plays a role in the ways in which an organization observes and describes itself (Section 2.1.1), the organization is likely to produce an *excessive* amount of differentiation between itself and the environment. As a result, there are many ways in which an environment can become observable for the organization, which opens new possibilities for routine enactment.

Autopoietic organizations and SL thus rely on opposite core impulses: SL induced routine enactment brings organizations into closer contact to an environment as it exist as a collection of other systems, while the self-production of decisions and communications distance the organization from this environment (Cheong et al., 2014). Table 2 and Table 3 describe differing strategies for routine enactment. *Table 2* details how the Carnegie School interprets routine enactment and the role of SL. *Table 3* shows autopoiesis theory frames routine enactment according to structural coupling principles. The relationship between routine enactment and SL is outlined as well.

Table 2: Carnegie School on Routine Enactment and Superstitious Learning

CARNEGIE SCHOOL **Strategy for Routine Enactment**	**Routine Enactment Mechanisms**	**Conditions for SL**	**Impact of SL Routine Enactment**	**Impact of SL on OL**
-*Happens through the simplification of external experience* References: Kim and Senge, 1994 March and Olsen, 1975 Heimeriks, 2010 Zollo, 2009 Gino and Pisano, 2011 Romme, Zollo, Berends, 2010	-Aims for coherence and predictability (e.g. in a coupling configuration A has expectation for the behaviour of B and vice versa) **(a) Low Horizontal Differentiation**: -Low degree of heterogeneity of actors' position in communication and task related domains **(b) High Integration:** -Coordination of organizational members' actions is focused on unified goals. -High degree of strength and directness in coupling between organisational members in different domains. -Subsystems are united in their implementation of organization's tasks.	SL occurs: -when experience based learning predominates -in situations with causal and outcome ambiguities -in situations when cause and effect are too distant in time and space -when there is two or more feedback learning loops -through institutionalisation of knowledge (e.g. during alliances) - There is a tendency for noticing salient errors at the expense of minor ones. -in settings with no pay off consequences -in setting when in which outcomes can be determined/observed only after sequences of actions have been performed. -in situations with temporal delays and non linearity	-Reinforcement of existing structural arrangements: SL cause and effect links are accepted by the system when they are similar to existing tight coupling configurations. -Increased Differentiation between Actual Coupling and Temporal Coupling domains: The temporal and the logical sequencing of tasks become increasingly separated and independent from each other. - No Horizontal Differentiation: Actors' position and interaction patterns within the communication flow become similar. -Total Integration: Completely routinized coordination of organizational members' actions towards one single unified goal.	-Performance Impact: Undesired results are erroneously attributed to external variables closely related in time and space. Success (and SL derived from it) leads CEOs to erroneously believe that their firms possess a special skill in relation to competitors) (Confidence-competence-paradox ;Overconfidence bias) -Knowledge and Routines in alliances cannot be located or cannot be used -Routines are negatively affected by experience and inertia . - Managers tend to notice less external events if these events have almost the same (identical) attributes than events encountered previously in either a direct or an indirect way (Almost Identical Biases) -Difficulties in credit assignment (ie how to attribute outcomes out of a sequence of actions and out of the antecedents of these action)

Table 3: Autopoiesis theory on Routine Enactment and Superstitious Learning

AUTOPOEISIS THEORY **Strategy for Routine Enactment**	**How it works/ Routine Enactment (Mechanisms)**	**Conditions for SL**	**Impact of SL on Coupling**	**Impact of SL on OL**
STRUCTURALLY COUPLED Happens through (a) addition of causal patterns (b) amplification and Abstraction of Experience References **:** Puranam, 2018 Tsang, 2004	***-Generate coherence but constantly redefine predictability according to moment- to- moment conservation processes***. **-Conservation mechanisms** (abstraction of the structural coherence under which historical process takes place). Includes compensation, homeorhesis and homeostasis mechanisms *The position of coupling elements within the*	Managers rely on superstitions only when they have to make a ***strategically important decision*** When ***competing decisions scenarios*** are involved Superstitious thinking and beliefs only where ***standard business practices and tools have failed*** When ***undifferentiated alternatives*** which are all equally attractive are present Superstitions are, ***arbitrary ideas*** which vary across	-With its clear cause & effect structure, SL can act as an ***abstraction and substitute of operational coherence*** within the system thus amplifying and supporting the existing structural domain. -SL introduces a ***change in the regulatory elements*** of the system, SL induced change may simultaneously modify all connected elements. This ***increases the synchronization among system elements***. -SL may introduce ***distortion of the criterion of validation***. When the expectations regarding the behaviour of a living system are not met, observers rely on information processing to adjust their expectations and modify their cognitive chains of explanation.	SL and faulty representations can ***improve decision making***/finding solutions provided that group ***share the same r****epresentations* Implies a ***degree of risk*** (impossible to know in advance if SL results in positive outcome or not) There is a relationship of ***complementarity*** between superstition and decision making Superstition as an ***alternative source*** of information in ***unstable*** situations Superstitions can be used in order to ***differentiate between alternatives***

Rudski, 2001 Hirshleifer et al. 2012	*structural domain* depends in the difference between the organisation and its structure. ***Criterion of Validation*** -Refers to the process of ***achieving autopoietic unity*** among various subsystems in the implementation of organizational actions.	cultures.	In the context of information overload, this may result in the creation of superstitious routines **-Conservation mechanisms**: By contributing to the ***recombination*** of system elements, SL may support the ***abstraction*** of the structural coherence under which historical process takes place	because they can give access to a richer set of ***associative links*** ***Biases*** caused by superstition ***do not occur at every level in the firm***

III) TOWARDS A THEORETICAL FRAMEWORK

3.1) Superstitious Learning Mechanisms: The Role of inert historical Facts and Disconfirmation Processes

As we have noted in Section 2.1.3, the autopoiesis theory uses disconfirmation processes as a part of the organization's self-description. Namely, every operation of the organisation (i.e. decision or communications) is a distinction between that which it is (a decision) and that which it is not. The distinction, however, "un-observes" the environment, which makes any external orientation difficult. The only way in which the environment can become observable again for the organisation is through the re-entry of the original distinction at the inception of the organization. In this context, the role of superstitious learning (SL) is crucial because it supports such re-entry processes: it makes the observable varieties of the environment partially visible because it produces a simplified and abstracted "copy" of the core distinctions of the organization.

SL achieves this by leveraging inert historical facts, disconfirmation processes and strategic ignorance. Namely, SL abstracts and simplifies the self-reproduced environment through *inert historical facts*. SL then compares this abstract, simplified environment to a (self-produced) environment with opposite characteristics through *disconfirmation processes* of its own. An inert historical fact is a mundane event that is no longer discernible and which leaves no trace in the environment (Dennett, 2013). This can be related to the autopoiesis theory, when the distinctions created in observations (i.e. known vs. unknown reality) are no longer fully visible because of the previously made distinction (i.e. the initial distinction "un-observes" some parts of the environment and this "un-observation" is reproduced by subsequent distinctions)

Disconfirmation processes involve comparing elements to their perceived opposites, which uncovers the properties of these elements (Taleb, 2012). Namely, in order to define what an element such as decision or observation is it is easier to consider what it is not, rather than to list its properties. In relation to SL's impact on organisations, the resulting contrast between two self-generated but different environments is what allows us to observe the "inaccessible"

environment in the first place. The strategy of learning in this case is to define something by its absence.

In the literature, inert historical facts are produced through processes such as strategic ignorance. *Strategic ignorance* refers to actions taken by an organisation in order to either obscure information that can threaten its knowledge, or reduce the overload of incoming information (Heimer, 2012). In SL, strategic ignorance is voluntary. For instance, SL is often maintained even if people know that the information is not true (Campbell, 1996). People choose to ignore errors because intuitions about situations are formed *before* any potentially falsifiable knowledge about these situations (Risen, 2015).

Recall that SL encodes causality in routines, but specifies that causal chains are arbitrary and can begin anywhere (Faye, 1993). For instance, events with close spatial temporal relations are likely to be considered causally related to each other (Kistler, 2013). However, this spatiotemporal closeness is fragile because an effect can precede a cause and the potential for backward causation can be successfully used in learning and in representations of the environment (Faye, 1993).

SL is thus important for transforming crucial characteristics of organizational learning such as errors, feedback, actions and justified knowledge into inert historical facts, because this type of learning reveals that the relationship between these characteristics is not necessarily causal. Likewise, when an object hits another, the brain interprets this as a single event rather than a set of events loosely linked to each other (Roessler, et al., 2011; Haselton and Nettle, 2006). Hence, routines, feedback and outcomes are all simultaneously part of the same event and thus are constitutive of each other (Desantis et al., 2015).

The causal relationship between routines and subsequent feedbacks (which in the Carnegie School's perspective is taken for granted) thus becomes an inert historical fact because both routines and their feedbacks happen simultaneously and are no longer discernable from each other. Once again, such a process can be directly linked to blind spots in the observations made by autopoietic systems. In this context, routine enactment and learning inescapably revolve around the reproduction of inert historical facts because these facts are always part of the original distinction of the system. In this context, SL is what allows us to highlight and to keep the unmarked, invisible part of this distinction for further purposes.

Finally, *randomness* is an operating principle of SL and autopoietic systems. For instance, causal misperception in probabilistic reasoning does not cause SL, while perceptions of randomness do (Dagnall et al. 2011). The system also tends to look for randomness and to collect information through contrasting counterfactual patterns (West and Lebiere, 2001), a process that is visible in SL. In autopoietic terms, randomness is essential for the self-reproduction of the system and is expressed in terms of heterarchic components. Namely, a system is *heterarchic* when all components of the system are autonomous with the potential to be ranked in any possible way (Luhmann, 1991). Routine enactment in "superstitious" terms, is thus set to enforce *randomness* expressed as *heterarchy* so that the system might be able to reproduce itself with reference to its own initial distinction.

In the next section, I will outline how this complementarity of processes between superstitious learning and autopoiesis respectively, contributes understanding to routine enactment.

3.2) A Superstitious Learning based Model of Routine Enactment

The present model of routine enactment and matching is a reconceptualization of Eggers and Kaplan's (2013) framework of recursive routines and capabilities. My focus is on how autopoietic and superstitious learning processes create an environment where routine enactment and routine matching to external opportunities occur in parallel rather than in a sequence. The main three propositions of the model are outlined below:

Proposition 1)*: Superstitious learning helps to enact routines in the organization by enabling the organisation to produce its own environment.*

Both SL and autopoietic reproduction of decisions and communication are consolidated by self-fulfilling anticipations. Once SL influences routines (and the representations involved in them), it frames subsequent actions, thus reproducing ''superstitious'' actions and routines further. SL thus has self-confirmatory function (Feltz et al., 2008). Likewise, an autopoietic system will anticipate changes in the environment by constantly self-producing (Luhmann, 1990). This anticipation of self- produced recurrences makes autopoietic systems prone to self-fulfilling prophecies (Kenny, 1989). Namely, an autopoietic system will always work

according to autopoietic principles because it picks only those elements that will allow autopoiesis (and the associated distinction between the inside and the outside) to be maintained. This process is shown in *Figure 1*:

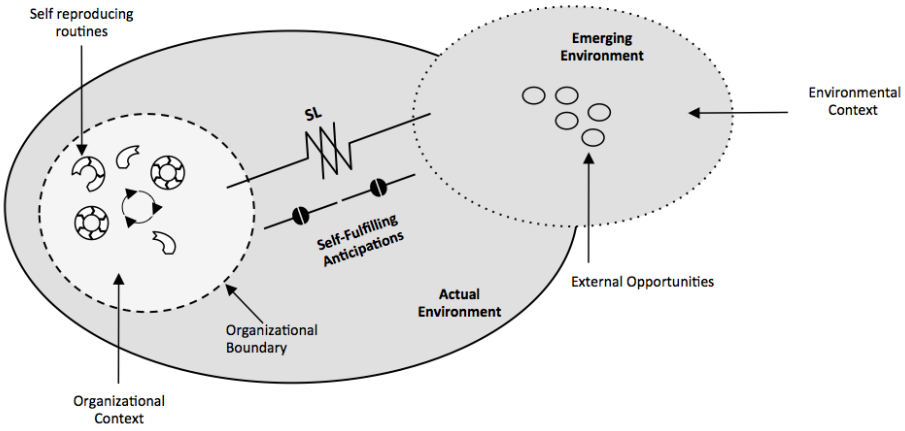

Figure 1: Routines self-reproduce in their organisational context. In so doing, they redefine the organizational boundary. Both routines and superstitious learning reproduce themselves according to self-fulfilling anticipations, which, allows them to project what external opportunities for routine enactment will look like in an emerging, self-created environment. Self-fulfilling anticipations help both SL and routines to pick those elements in the environment that could help them to reproduce further.

Since an autopoietic system produces self-fulfilling anticipations of environmental changes, it is understandable why it would superstitiously learn in ways that produce self-fulfilling anticipations as well. Thus during the first stage of the model, autopoietic processes in an organization will rely on SL in order to consolidate themselves. In practice, this means that the organizations may focus on those features of the (observed) environment that will reinforce their enacted routines.

In the second stage of this model, SL contributes to this consolidation of autopoietic processes by activating the process of *autonomous cooperation and control (ACC)* between the organization's components. ACC appears in autopoietic systems and specifies that system departments have the capacity to render decisions independently and thus to reproduce system components (such as routines and decisions) in any conceivable order (Hülsmann et al., 2008). This independence results in a state of heterarchy (Section 3.1). SL functions in heterarchic terms as well because it can associate any action to any outcome provided that they are close enough in time. Namely, people and systems are more likely to superstitiously link a cause to an effect if both occur in a close temporal sequence (Shermer, 2002). While SL is unfolding around causal chains, these chains are random and arbitrary (Section 3.1 and

2.1.3). Thus, because causal relationships in SL are essentially random and heterarchic, they will fuel and amplify heterarchic autopoietic processes of routine reproduction. *Figure 2* documents this process:

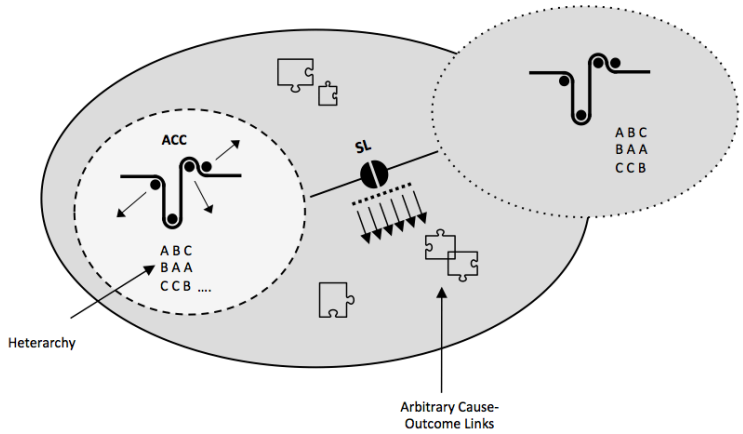

Figure 2: Once routines operate in autopoietic terms, they act in a state of heterarchy and can be ordered in any conceivable way (hence the different letter order). SL is heterarchic as well and thus picks arbitrary cause-outcome links for the organisation in the environment and brings them into the organisations. This further amplifies heterarchy processes for routines.

Proposition 2)*: Superstitious learning helps the organisation to enact routines by producing simplified and abstracted observations of the environment through a process of disconfirmation.*

Once the organisation has the capacity to observe or create its own environment, the issue is to abstract this environment in order to compare it with alternative observations later on. Through *disconfirmation processes*, routines are compared and contrasted to constructed "external opportunities" by discarding their irrelevant attributes. It thus becomes possible to create an abstracted, simplified environment with high-level generalizable relations between the organization and the environment.

The causal relationships in SL are by themselves an abstraction of the potential relationships between routines and, the environment and as such, would reinforce any disconfirmation processes at work. SL can thus achieve the simplification of an organizational self -produced environment by using *inert historical facts* and *strategic ignorance* (Section 3.1). This can be seen in conjunction with autopoietic processes that conceptualise communication as actions for simplified orientation and self-description (Section 2.1.1).

For routine enactment, comparing strongly contrasting interpretations of the links between routines and opportunities helps to understand the nature of the environment of other systems and organizations (alternative observations) making this environment observable for the organisation. The whole process is documented in *Figure 3*.

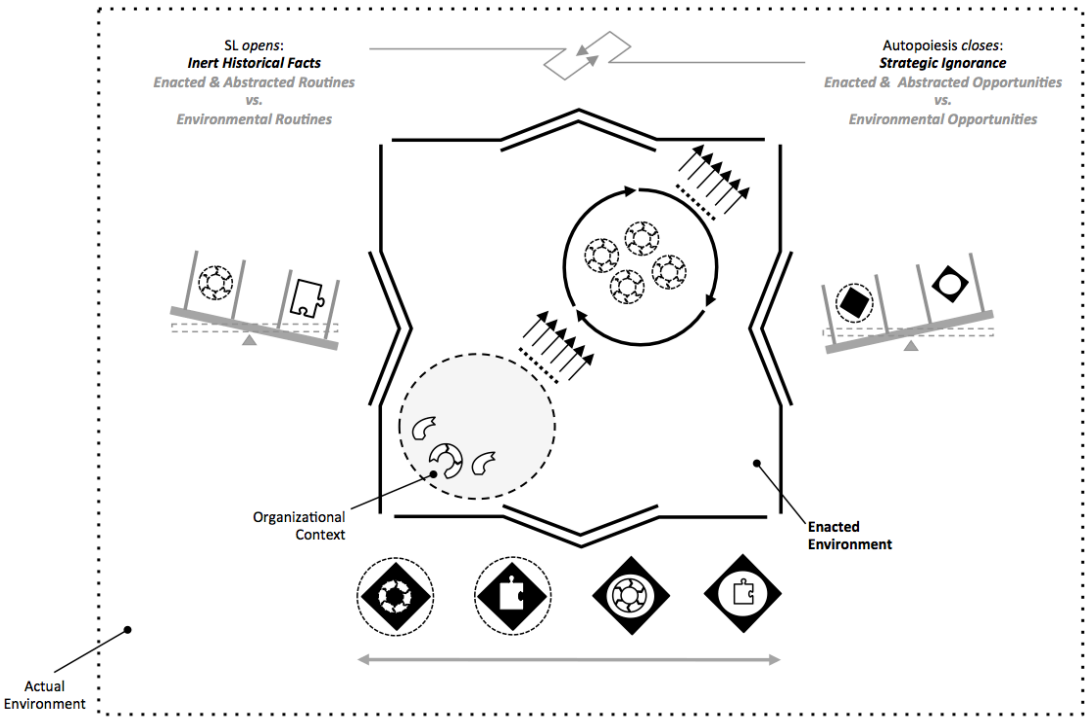

Figure 3: Once organisations have constructed their own enacted environment, they can compare their abstracted routines to the routines in the environment. Because organisations cannot do it themselves (they work in autopoietic terms), they rely on SL for this task. SL opens the organisation by comparing routine enactment within the organisation to abstracted enactment opportunities in the ''real" environment of alternative systems.

Proposition 3)*: Superstitious learning helps to enact routines of an organisation by contrasting routine enactment in the amplified, self-created environment of the organisation with the perceived opportunities to behave (act) in the external environment of other systems.*

Once the organisation has created an abstracted environment of its own for routine enactment, it can compare it with alternative observations of the environment that is located outside of the original distinction. As a result, opportunities of the environment for other systems may become observable. In this context, SL has the function of opening organisations to change (Section 2.2.2).

As we have noted in Section 3.1, SL collapses categories of observations into a single and unified one. Organisations are restricted to a particular mode of operation (i.e. decision and communications) (Luhmann, 1990). Through the conflation of categories of observations, SL opens "autopoietic" organisations to different modes of operation and communication (e.g. communication of presence or absence of participants in interaction systems) (Section 2.1.1) (Seidl, 2004). This opens new opportunities and new dimensions for routine enactment while allowing communication between different types of social systems including societies, interactions and other organisations.

IV) DISCUSSION AND CONCLUSION

This paper intended to explore the joint impact of superstitious learning (SL) and autopoietic processes on routine enactment. The motivation behind such a line of inquiry is twofold. First, the autopoietic approach has not explicitly explored superstitious learning in contrast to the Carnegie School, where SL and error learning are significant topics of inquiry. As a result, the predominant view on SL is shaped by the information processing approach: organisations enact their routines in a close correspondence to objectively existing opportunities in the environment.

In this context, SL is considered as causality error that significantly compromises such a relationship. I argue that the autopoietic theory provides a more nuanced role for SL because it sees self-organisation (rather than a strict adherence to external contingencies) as a key dimension for learning and change (Hernes and Bakken, 2003). SL thus finally acquires a functional and operational role for organisations because its impact depends on internal organisational processes rather than on external arrangements.

Second, both autopoietic processes and superstitious learning share key similarities and differences in their operations. This paper shows that both SL and autopoiesis theory rely on distinction making, rendering aspects of an environment either observable or not observable. Namely, both are articulated around a selective focus on some types of information at the expense of others. By enforcing selection and choice, both SL and autopoietic processes create blind spots of observation of the environment for organisations.

As this paper shows, SL and autopoietic processes create environments from which structurally coupled organisations can learn and where routines can be safely enacted. By creating their own abstracted and amplified environments, structurally coupled organisations are able to determine varieties of observations of the "real" external environment (i.e. an environment of other systems because the real environment is not ontologically reachable) and to enact routines accordingly.

The contribution of superstitious learning to routine enactment is thus crucial because it produces excessive causal patterns in the "real" environment (unlike autopoietic processes which are self-referential and thus do not reach the environment directly). This creates more links for comparison between the self-created environments of organisations and alternative observations of that environment, which allows us to anticipate environmental change. However, our claim that organisational learning is structured by blind spots of observations prompts questions about the nature of learning itself. Within this information-processing view, organisational learning allows organisations to survive through adaptation to external environmental changes (Becker et al., 2005).

The notion of self-created autopoietic environments suggests that organisational survival is the ultimate purpose because autopoietic systems can only choose those features which would allow them to self-produce. Organisations will survive with the issue being the only form such survival can take. In relation to divestitures for instance, Von Krogh and Roos (1994) show that some traces of departments, routines and practices of a firm remained and continued to have an impact even if parts of the firm were sold off. Such "phantom limb" effects echo the creation of invisibility as outlined by Luhmann (1990): organisations leave traces that remain in the environment long after these organisations are gone. For routine enactment, the implication is that the links between routines and the external world are established by the blind spots of cognitive operations. Enacting and matching routines is thus mostly about finding a predestined path in the dark.

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ESSAY 2 :

Finding a black Cat in a dark Room: Dynamic self-organizing Perceptions of Uncertainty and Complexity in Multimorbidity Care

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Multimorbidity (MM) raises important challenges for the coordination and provision of care. It involves a complex pattern of interdependencies between conditions, medications, and healthcare systems. In order to understand the nature and the impact of such challenges, we conducted a qualitative study on healthcare practitioners' perceptions of complexity in multimorbidity. In so doing, we relied on two theoretical streams: a CAS (complex adaptive systems) framework including stigmergy and chaos theories on the one hand, and theories of relative ignorance on the other hand. Our aim was to (i) differentiate uncertainty from complexity in multimorbidity care and (ii) provide an insight into how administration collaborators in healthcare settings structure care delivery for care providers. We found that administration collaborators provide a framework for understanding uncertainty in workflow and coordination activities, which is then adopted and resolved by care providers.

1. INTRODUCTION

Multimorbidity refers to multiple co-occurring chronic or long term diseases (Doessing and Bureau 2015). As such, it challenges the current single disease model that relies on a deterministic relationship between causes (aetiology), effects (illness) and interventions

(treatment) (Bower et al., 2012). Namely, diseases do not have an additive effect on health outcomes, but rather operate according to a non-linear pattern of complex interactions (Sturmberg et al., 2017). Multimorbidity cannot thus be reduced to disease specialism and as such is at odds with the current trends towards specialisation and the stiffening of professional barriers in medical sciences (Marcum, 2017).

This non-linear approach has prompted many researchers to interpret the management of multimorbidity in healthcare through the lens of complex, adaptive systems (CAS) (Anderson et al., 2005; Lessard, 2007; Sturmberg, 2020). A CAS is focused on the relations and interconnections of the system components rather than on the individual components themselves (Cillier, 2005; Stacey, 2003). Complex adaptive systems are defined by their self-organisation: the behaviour of units and agents in the system are governed by local rules which ensures that these very units have no conception of the order they are generating (Eppel and Rhodes, 2018). As a result, the outcome of the interactions between individuals, organisations and systems are emergent and unpredictable because their sum is greater than their parts (Blaikie, 2007).

CAS has a wide application in healthcare settings. For instance, hospitals were examined in terms of complex adaptive systems where organisational processes self-organise in such a way as to correspond to the outcomes of the patient (Anderson et al., 2003). CAS was also successfully applied to the coordination of multi-disciplinary teams in MM care (Pype et al., 2018). Team members provide more comprehensive, inclusive and flexible care when they act as collective whole than when they act individually (Letiche, 2008). CAS theory also provides an explanation about how hospital departments cooperate together. For instance, diagnosis, categorization and discharge depend on the linkages between different departments and services (Nugus et al., 2010). Members of the emergency department integrated non-clinical aspects of their patients in their care plan in order to engage other departments in multidisciplinary care teams.

However, CAS is rarely applied to the ways in which non-clinical healthcare actors (such as medical secretaries, study nurses and hospital orderlies) cooperate with healthcare providers. Non-clinical healthcare actors are often neglected in the literature as the focus is on nurses, doctors and healthcare practitioners with direct contact with the patients (Stisen et al., 2017). However, the role of non-clinical healthcare actors is crucial for the alignment and

coordination of tasks, as well as in the regulation of workflow. For instance, medical secretaries are engaged in articulation work and information gatekeeping: by registering, updating and renewing patients records, they shape work processes in hospitals and patient trajectories (Møller and Vikkelsø 2012). We thus aim to understand the ways in which healthcare actors with no direct contact to the patients interact with healthcare providers in MM care through the framework of complex adaptive systems.

However, in order to understand the interaction between non-clinical and clinical healthcare actors in MM care, it is necessary to examine the place of human intentionality in CAS. Despite wide applications of CAS principles in the healthcare literature, some researchers argue that CAS mechanisms are not directly related to human intentionality and thus cannot be fully applied to human actors (Paley and Eva, 2011). For instance, a core principle of complex adaptive systems is that agents are not aware of the order they are generating (Pype et al., 2017). This is a principle that directly derives from the animal world. For instance, termites exhibit orderly patterns of behaviours, but they are not aware of the ways in which their individual activities relate to the outcomes they produce with others (Paley and Eva, 2011). However, this cannot be fully applied to healthcare actors because they are intentional beings who operate in goal oriented medical systems (McKelvey).

Thus, in order to apply CAS principles (such as self-organisation) to healthcare settings, it is necessary to determine the place and the meaning of human intentionality in CAS and complexity theories in multimorbidity care (Tuffin, 2016; Juarez, 2011). In order to achieve this aim, we state that complexity is not only composed of numerous interdependencies but also includes uncertainty and relative ignorance. Namely, both termites and humans display ignorance of the existing interdependencies in a complex system (Marsh and Onof, 2008). The difference is that humans know that interdependencies unknown to them exist, while termites do not. The implication of this particular form of relative ignorance is that ultimately, something can be known about what is unknown (Gross, 2007). This relative optimism defines uncertainty as something that *should* be acted upon: human actors both operate in terms of uncertainty (as all interdependencies cannot be known) and try to solve this uncertainty by identifying unknown domains through agreement on common goals and outcomes (Gross, 2016).

This dependence on both relative ignorance and potential uncertainty is what differentiates intelligent human systems from animal ones: only intelligent systems are able to represent what they don't know (Knudsen, 2017). We thus believe that highlighting the intersections between uncertainty and relative ignorance (a hallmark of human actors) on the one hand, and CAS principles on the other, will not only allow us to understand how CAS can be applied to MM care, but will enable us to understand how non-clinical healthcare actors cooperate with clinical actors in the coordination of complexity in multimorbidity care.

We thus conducted a qualitative study that focused on the perception of multimorbidity complexity by non-clinical actors and healthcare providers in a Swiss university hospital. In the theoretical part of this paper, we will first outline the different components of multimorbidity complexity (workflow complexity, coordination complexity, care delivery complexity and patient complexity). In so doing, we will explore how these complexity typologies relate to two complexity theories (stigmergic and chaos theories respectively) and how these theories intersect with relative ignorance of interdependencies as well as uncertainty. We will also outline how non-clinical actors play a role in workflow and coordination complexity and how healthcare providers deal with patient and care delivery complexities.

Building on this theoretical framework, we will analyse and code the data provided according to the professional roles of healthcare actors (both clinical and non-clinical). We will first outline general uncertainty-enhancing and uncertainty-reducing factors from medical experts within the field. In parallel, we will outline the perceived operations of workflow and coordination complexities of the non-clinical actors (secretaries, reception staff and study nurses). These operations will provide us with an understanding of the perceived landscape for the dynamics of different complexity types for nurses, senior doctors and assistant doctors. This will also allow us to explore how the management of workflow and coordination complexities by non-clinical actors impacts healthcare providers' response to patients' and care delivery complexities. The model will allow us to understand how both clinical and non-clinical actors can shape complexity and uncertainty in relation to each other.

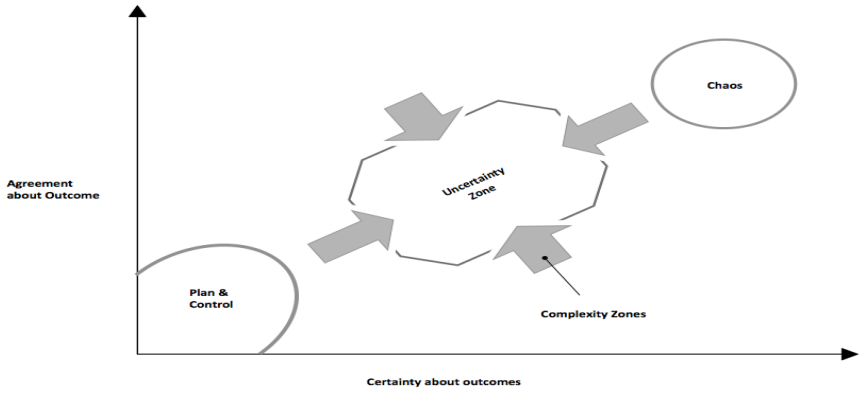
2. THEORETICAL FRAMEWORK

2.1 Defining the uncertainty zone through relative ignorance

Complexity is characterised by the number of its interdependencies (i.e. the more independencies, the higher the level of complexity). In multimorbidity care, the number of interdependencies (and the degree of complexity) is too high to be known and identified with certainty (Clancy et al., 2008). In practice, this means that healthcare practitioners cannot possibly be aware of all existing interdependencies and relationships because they are uncertain about the potential outcomes of their actions.

Pype (2017) observes that healthcare practitioners operate either in the "*complexity zone"* or in the *"chaos zone"***.** In a complexity zone, there is not enough certainty to plan actions towards a certain goal, but there is a general agreement on the result of a specific action. In a chaos zone by contrast, the group of healthcare providers cannot agree on intervention results because there is no relationship between actions and outcomes (e.g. an outbreak of an unknown disease where previously agreed measures do not have the expected effect).

In multimorbidity care, the uncertainty zone is located between chaos and complexity zones. Namely, team members cannot possibly be aware of all the existing interdependencies. This relative ignorance of interdependencies applies to both the links between actions ant outcomes and to the agreement levels between team members (Burtscher et al., 2020). Ignorance is relative because the uncertainty zone contains *both* known and unknown interdependencies: a care scheme is likely to contain shared action sequences whose outcomes are widely known (e.g. routine analysis of blood data) and elements whose outcomes are either unknown or uncertain (e.g. the results of drug interactions). *Graph 1* shows that known interdependencies (the plan and control area) and unknown interdependencies (the chaos area) determine complexity. Complexity, in turn, determines uncertainty both through what is known and what is *not* known about potential outcomes of certain actions.



Graph 1 (partly inspired by Paley, 2017) shows that the uncertainty zone is constructed in equal measure by the chaos zone (where no certainty and agreement exist) and the plan & control zone (where there is complete certainty about outcomes).

With its focus on the micro-level of healthcare systems, CAS theories and healthcare related research on complexity are able to outline how such uncertainty zones are structured. Namely, complexity and related uncertainty in medical clinical practice for multimorbidity are divided into two domains (1) patient related factors (case complexity), and (2) care delivery related factors (care complexity) (de Jonge et al., 2006; Doessing & Burau, 2015; Islam et al., 2016). Subcomponents of care and case complexity categories include different types of complexity, namely workflow complexity, coordination complexity, care delivery complexity and patient complexity (D'amour et al., 2008). An uncertainty zone in medical practice is thus determined by relative ignorance and structured through different types of complexities.

The question is how the uncertainty zone differs from complexity and chaos zones in terms of the agreement and certainty dimensions. Both complexity and uncertainty stipulate that healthcare practitioners can agree on provisory courses of action, despite being uncertain about the outcomes. As we have noted, however, the uncertainty zone is determined by a relative ignorance about interdependencies between outcome certainty and outcome agreement. Namely, healthcare practitioners may be certain and aware of some aspects of outcomes while ignoring other aspects of the same outcomes.

Uncertainty is thus characterised by relative ignorance. In turn, relative ignorance is defined by its degree of temporality and intentionality (Gross, 2016). Namely, intentionality refers to the degree to which an individual is unwilling to know. In genetic testing, for instance, the individual may choose not to know the details of his/her genetic profile (Cowley, 2016). By contrast, when people make erroneous assumptions about how a thermostat works, this is not because they do not want to know, but because they ignore the laws of physics. Temporality refers to the possibility of knowledge gaps being filled within a certain time span. For instance, researching the potential risks of a new drug is relatively high on the temporality dimension: there is a relatively high possibility to know the harmful effects of the drug after a testing period. By contrast, studies and theories on the end of the universe classify as (extremely) low on the temporality ladder because they cannot be verified in any foreseeable future.

Such a framework allows us to determine what uncertainty in multimorbidity care is about. As *Table 1* shows, uncertainty concerns temporality (i.e. the duration for filling a knowledge gap) when healthcare practitioners intentionally ignore issues that won't be clear in the near

future. Conversely, an issue can be known in a short period of time, but healthcare practitioners are not aware of this because they lack the necessary knowledge to approach this issue accurately. In this sense, uncertainty concerns intentionality: to what extent are healthcare practitioners willing to learn about something they ignore? By contrast, there is no uncertainty when healthcare practitioners intentionally do not want to know about an issue whose outcome won't be clear in the near future.

Table 1: *Uncertainty Location*

Uncertainty Levels	**Uncertainty Focus**
Low Intentionality-Low Temporality	Uncertainty refers to temporality and intentionality
High Intentionality-High Temporality	No uncertainty
Low Intentionality-High Temporality	Uncertainty refers to intentionality
High Intentionality-Low Temporality	Uncertainty refers to temporality

For this reason, unlike complexity and chaos zones, an uncertainty zone is highly mutable as it changes and expands across temporality and intentionality dimensions.

2.2 Uncertainty zone processes and contents: Stigmergy Theory and Chaos Theory

Chaos and stigmergy theories are both part of the CAS framework and are both applied to the multimorbidity domain as metaphors for complexity (Dipple et al., 2014). While they share many CAS principles (such as order outcome), they differ in their approach to historicity. While chaos theory starts from stable initial conditions (that are changed by perturbation and feedback later on), the stigmergy theory specifies that the starting point relates to seemingly disorderly and separate actions. Both chaos and stigmergy theories tend towards order as the main endpoint (Parunak, 2005).

Given their different approaches to initial conditions and outcomes, chaos theory and stigmergy theory frame complexity typologies in different ways. For instance, workflow and coordination complexities often operate according to stigmergy principles (Heylighen, 2016), while care delivery and patient complexities are understood in terms of chaos theory (Arndt, 2000).

(a) Stigmergy: Coordination and Workflow Complexities

Stigmergy theories focus on how complex sets of relationships can generate simple and orderly behavioral patterns (Marsh and Onof, 2007). Stigmergy is an indirect mechanism of coordination between actions*:* system actors perceive the effect of an action and this perception is what stimulates the performance of a subsequent action. In practice, this means that the action of an individual (e.g. edit of a Wikipedia page) leaves a trace in the public space (change in the Webpage), which prompts other individuals to act within the same public space and build on the original action further (adjust or change the original edit). The outcome (the final state of the webpage) is collective and coordinated, but this coordination can occur only if all the actions in the system are traceable and observable. If an action leaves no trace, then no system actors can act on it.

Workflow complexity is characterised by a high number of intricate activities, roles, interfaces and environmental and structural contingencies (Cardoso, 2006). In stigmergic terms, however, the environment does not have a directly active role in workflow complexity*:* only traceability of actions and the shared artefacts do (Mariani, 2018). In healthcare literature, shared artefacts represent a trace in the workflow: activities are recorded in the physical environment and this record is subsequently used to organise collective actions and behaviours (e.g. an IT program which organises workflow for the day) (Møller, N. L. H., & Bjørn, 2016). The ability of the environment to act as a medium depends on its accessibility and availability to all agents within the system. For this reason, core functional units (i.e. multi-disciplinary teams dedicated to the care of one patient) do not transfer information according to purported zones of activity, but rather according to the changes in their group composition over time (Kannampallil et al., 2016).

In stigmergic terms, the goal of any artefact design (e.g. a whiteboard) is that artefacts should function as invisible tools. In a healthcare setting, for instance, registration systems become so ubiquitous that participants are no longer aware of them even if they regularly use them for communication (Lewis, 2013). This represents a form of relative ignorance and uncertainty, and explains how people can act on aspects about which they have little or no knowledge about (Majchrzack et al., 2007).

Stigmergy also gives us an understanding of the mechanisms of *coordination complexity* in MM care. Coordination complexity occurs when there are no tools (such as feedback loops or verifications) to ensure that communications result in intended actions (Havens et al., 2010).

In stigmergy terms, however, this communication-action alignment is replaced by traceability. When medical specialists attempt to search for relevant information within a partly unknowable knowledge landscape, they do not need to be aware of specific goals or of each other's mental models (Runtu et al., 2019). They only need to transfer information via the work they do in the medium in which they operate (e.g. hospital department).

In multimorbidity care, goals are thus in a constant state of attainment: positive feedback, perturbations and contingent events have the same potential of hindering as of facilitating movements towards the goal (Lewis, 2013). Goal and action ambiguity is thus a form of relative ignorance and uncertainty that can be partly explained by stigmergy principles.

(b) Chaos Theory: Patient and Care Delivery Complexities

Chaos theory applies to systems that are highly sensitive to their initial conditions. Feedback and small changes bring the system to either an aperiodic or a stable equilibrium state and thus act as an attractor. When a system reaches an aperiodic state, the slightest change in the system state will cause the state to diverge. Chaos theory thus relies on determinism (the system will always end in equilibrium) where seemingly random behaviour is the result of relatively simple non-linear systems. At the same time, chaos theory also relies on unpredictability. When feedback exceeds some critical threshold, this results in phenomena of an altogether different scale and quality in comparison to everything that preceded it (Rickles et al., 2007). Minor perturbations can thus lead to dramatic and unpredictable changes at some point in time (e.g. the butterfly effect).

Patient complexity can be clarified through interactions between chaos theory and uncertainty (i.e. relative ignorance). Namely, Coventry (2015) pointed out that patients experience MM as a "*moment of complexity*": they don't experience multi-morbidity in terms of number of symptoms, but rather as a complex state with overlap between emotional and physical symptoms. In this sense, both the patients and the healthcare providers are confronted with their relative ignorance: the healthcare provider cannot access the patient's "moment of complexity" experience, while this very ‘’moment’’ experience prevents the patient from accessing concrete aspects of their illnesses.

Chaos theory is helpful in the sense that it allows us to understand how this form of relative ignorance is produced. Namely, the "moment of complexity" is the result of small

perturbations (e.g. daily instances of physical autonomy loss) that after reaching a tipping point, lead the patient to a "moment of complexity" in the understanding of his/her own illness (Lartey, 2020). A "moment of complexity" experience is both an instance of ignorance (because it is an experience which obscures details) and an attractor which constantly self-organises itself in predictive ways. That is to say, the moment of complexity is fleeting (it is after all a *moment*) but it will always recursively return to the initial conditions that produced it (e.g. the illness' physical symptoms).

The intersection between *care delivery complexity*, chaos theory and relative ignorance can be located in patients' ability to balance their medicines, emotions and social resources (West et al., 2006). Chronic health patients may develop self-managing and social-coping strategies outside of the healthcare context. Because the clinical staff has no direct knowledge of these strategies, it operates under conditions of uncertainty, especially since the extent to which patients' behaviour and the clinical care plan can be aligned is unclear.

In such cases, chaos theory interprets uncertainty as something that can be easily integrated into a patient-physician relationship. Namely, the balancing act (e.g. adaptation to a new lifestyle) in which patients engage in, as well as their preservation mechanisms correspond to a processes leading to an equilibrium state (a balance) which then can manifest itself as an attractor (an attractor is when this balance is achieved). Both patients and clinicians aspire to reach an equilibrium state within care delivery complexity, a state of minimal potential energy.

(c) Interdependencies between complexity types

Coordination, workflow, care delivery and patient complexities are established typologies in the literature. However, while their inter-relationship is well documented, CAS theories are often not consistent about what constitutes these complexities in the first place. In complex adaptive systems, for instance, a large number of actors is what characterizes both workflow and coordination complexities (Sweeney and Cassidy, 2002). There is thus no real differentiation between workflow and coordination complexity as they display the same characteristics and components (Paley and Eva, 2011, Turabian, 2018).

In this paper, we thus attempt to define both the content and the inter-relationship between various complexity typologies. On the basis of stigmergy principles, we state that workflow

complexity depends on the availability of zones for actions, while coordination complexity is characterised by its goal attainment state. Chaos theory allows us to determine that care delivery complexity depends on the perception of alignment between doctors and patients while patient complexity is constituted of moments of complexity. We thus aim to show how these various types of complexity interact in relation to both clinical and non-clinical healthcare actors.

2.3 Complexity for non-clinical healthcare actors: Workflow Complexity and Care Complexity

Care providers and non-clinical healthcare actors are not confronted with the same type of complexity, uncertainty and relative ignorance. Non-clinical healthcare actors have no direct contact with patients care scheme and diagnosis and hence are not confronted with patient complexity and care complexity. By contrast, care providers such as nurses and doctors are associated with all the types of complexity listed in the CAS literature. This includes not only patients and care-related complexity, but also workflow and coordination complexities. The role of non-clinical healthcare actors in solving and managing complexity is not explored in detail in the CAS literature. Non-clinical healthcare actors are interpreted through a CAS lens when they are part of the primary care team, but their actions are rarely the focus of research (e.g. Druss and Mauer, 2010).

However, research on the practices and contributions of non-clinical health actors show that their activities are crucial for solving workflow complexity and coordination complexity (Redaelli and Carassa, 2015). Collaboration between non-clinical healthcare actors and care providers occurs during transition of care across hospital departments (e.g. hospital orderlies, medical secretaries and registration assistants) (Seidelin et al., 2018). In this context, non-clinical personnel have a crucial role in ensuring that collaboration between different departments operates smoothly. For instance, care delivery actors (such as nurses and doctors) tend to make errors (e.g. by omitting patient information) during shift changes (Bossen et al., 2014). In this context, non-clinical healthcare actors such as hospital orderlies, play a crucial role in sustaining a common ground for care transition during patient transport and patient mobilization (Seidelin et al., 2018).

The digitalization in healthcare, notably through the development of electronic health records (EHR) has ensured a closer collaboration between non-clinical and care provider healthcare actors, notably in the area of workflow and care coordination (Aarhus et al., 2018). In most hospitals, clinical and non-clinical actors use and share the EHR and registration systems. As a result, work practices become more tightly coupled and interdependent. For instance, nurses do not always have the time to register their activities (e.g. initiating plans for care and treatment in the EHR) in real time (Bossen et al., 2014). This can be supplemented by medical secretaries when they update crucial information for care plans such as patients trajectories in the EHR (Seidelin et al., 2018). In this way, the work of medical secretaries becomes more tightly linked to other professions such as nurses and doctors). Medical secretaries are brought to perform some aspects of the tasks that were previously done by other professions.

Non-clinical healthcare actors are also involved in '*'boundary object trimming''* (Bossen et al., 2014) and hence play a crucial role in managing coordination complexity. Namely, EHR, internal digital records and IT facilities in hospitals are boundary objects: they are both plastic enough to accommodate local needs, yet retain a common identity across hospital departments (Aarhus et al., 2018). One of the most important effects of boundary objects is to standardize practices for coordinating different courses of action for common goals (Spiehl et al., 2020). In this context, non-clinical healthcare actors (such as medical secretaries) perform articulation work on digital records and databases for healthcare providers (Bossen et al., 2014). Medical secretaries constantly maintain and update the structural form of internal registration networks and EHRs by registering all types of data. This contrasts with the practices of care providers (e.g. nurses) who are only concerned with recording the type of information that will allow the patient's treatment to proceed (Nugus et al., 2010).

The activities of care providers and non-clinical actors are thus both complementary and increasingly co-dependent. However, there is still no exploration on how non-clinical actors shape the response of care providers towards patients' and care delivery-related complexities. We will show through stigmergy principles that non-clinical healthcare actors provide a workflow and coordination environment so that care providers can face care and patient related complexities adequately.

3. METHODS

3.1 Research Settings and Participants

We used a single site case study design, which allowed us to explore coordination and interactions between healthcare practitioners from different domains (Yin, 2003). Namely, we conducted a qualitative study that relied on semi-structured interviews with collaborators of an infectiology department (ID) in a Swiss university hospital. Our study at the ID was guided by our interest in the perceptions of multimorbidity. The ID department dealt with both multimorbid and non-multimorbid cases, which provided grounds for comparison. Moreover, infectiology is at the forefront of current complexity and multimorbidity debates in the literature. For instance, members of infectiology departments are in constant contact with complexity, as they have to take into account interactions between the drugs to treat infections and the co-morbidities of the patient (Havens et al., 2010). An ID department was thus an ideal setting to explore complexity and uncertainty in multimorbidity care.

Our aim was to have a cohesive, general overview of the ID's department perceptions of multimorbidity-related complexity. Therefore, in collaboration with the clinic director, we interviewed all the available members of the department regardless of whether they were directly involved in care delivery or not. As a result, we interviewed those collaborators who did not have a direct contact with patients and care delivery (i.e. administration and reception collaborators as well as study nurses) and those who did (i.e. assistant doctors, senior doctors and nurses). This differentiation was based on the theoretical framework in Section 2.3. Since this paper aims to explore the collaboration between non-clinical and clinical actors in MM care, the framework associated workflow and coordination complexities with non-clinical healthcare actors, while patients' and care related complexities were related to healthcare providers. As a result, we conducted 43 interviews in total. The complete participants list can be found below:

Table 2: Participants Distribution-Non-clinical actors

Administration/ Study Nurses	**Number**	**Code**	**Complexities Focus**
Secretariat	4	E	Workflow & Coordination Complexity
Reception	6	H and F	
Study Nurses	8	D	
Total	18		

Table 3: Participants Distribution-Care provider actors

Care Delivery	Number	Code	Complexities Focus
Senior Doctors	7	G and I	Patient and Care Delivery Complexity
Nurses	10	C	
Assistant Doctors	8	D	
Total	25		

Data Collection

(1) Exploratory Phase Data collection

At this stage, we interviewed 10 experts from different healthcare domains in order to have a generalized understanding of complexity, knowledge and uncertainty of multimorbidity care (details on the domains can be found below). Our interview schedule focused on knowledge production, knowledge coordination and learning processes in co-morbidity care. Our aim was to generate external general factors for uncertainty perception. The interviews were conducted by two authors of this paper namely AS, an organization doctoral candidate and SBM, a senior researcher, between August 2015 and November 2016.

Table 4: Distribution of Healthcare Experts Participants

	Function and Domain
A 1	Senior Doctor Anaesthesiology
A 2	Clinic Director Gerontology/ Internal Medicine
A 3	Professor, Chairman and Director, Delegate for Special Tasks Department Radiology and Nuclear Medicine
B 1	Senior Doctor Internal Medicine
B 2	Clinic Director Gastroenterology
C 1	Clinic Director Orthopaedic
C 2	Head Medical Strategy General
C 3	Clinic Director Neurology
D 1	Clinic Director Heart and Heart surgery

(2) Main Data collection Phase

On the basis of insights gained from the exploratory phase, we designed an interview guide focused on ID's collaborators perceptions of complexity for both multimorbid and non-multimorbid cases. All 43 interviews were conducted by AS and SBM between March 2017 and August 2017. Interviews were conducted in the language that was most familiar to the respondent. As a result, 24 interviews were conducted in German, 17 interviews in English and 2 in French. The interview guide was developed in two stages.

First, we conducted preliminary pilot interviews with ID collaborators including assistant doctors, senior doctors and nurses. Building on the feedback from these interviews as well as on refined references to the CAS literature, we restructured our interview schedule with the following topics: ID's collaborators perceptions of complexity, strategies and practices for multimorbid patient care and ID's collaborators background and daily activities. In the second phase, our interview schedule was refined during a round-table discussion with 12 department members. This allowed us to ensure that the interview schedule would correspond to the ID's specific context.

Data Analysis

(1) Analysis of the Exploratory Phase

Our aim for this phase was to extract generalized factors of uncertainty external to the ID. We intended to use these factors to complete and illuminate the complexity processes within the ID proper. Hence, AS transcribed extracts from interview recordings, which amounted to 28 pages in total. The raw data was structured by a broad coding scheme derived from the literature: AS looked for indicators of relative ignorance (uncertainty) such intentionality and temporality (Section 2.1). With further coding and analysis rounds, AS refined the coding scheme in order to obtain more specific general categories. As the categories were meant to be adapted to the participants from the main data collection phase (i.e. ID's participants), AS did not generate specific sub-categories.

(2) Analysis from the main data collection phase

From a total of 43 audio interview recordings, 38 interviews were transcribed in their totality. One interview relied on notes (i.e. the participant concerned did not want to be recorded) and two interviews conducted in French were partially transcribed by AS. All interviews were transcribed and analysed in their original language and illustrative quotes were later translated by AS for the purpose of the present paper.

We obtained 320 pages of single space transcripts data that we stored and analysed in NVivo 11 (a qualitative data analysis software licensed by QSR International). This data was analysed according to the systematic inductive approach (Thomas, 2006). First, we read all the transcripts and discussed the meaning of interview segments. As a result, we developed a preliminary coding frame that was used by AS in order to code all transcripts. Second, AS and SBM identified significant coded segments and refined the coding scheme in several rounds. This process was iterative as we relied on our preliminary findings to return to the available literature and redefine our coding scheme. AS recoded the transcripts using the new coding scheme.

The emerging categories were then refined according to the results and the theoretical frameworks in the literature. This allowed us to obtain both overarching general categories and more specific lower-level categories on complexity perceptions. The systematic inductive approach also allowed us to identify relationships among the categories. We focused on the difference and similarities in perceptions of complexity across nurses, study nurses, the secretariat and the reception personnel, senior doctors and assistant doctors.

AS then highlighted the difference between those participants who provide care directly and those who don't. Namely, the focus was on how non-clinical healthcare actors provide a coordination and workflow environment for healthcare providers in the face of patient and care related complexities. The administration staff and study nurses (who do not have direct contact with patients) were analysed in terms of workflow and coordination complexity while care providers (nurses, senior doctors and assistant doctors) where analysed in terms of patients complexity and care delivery complexity. AS's motivation for doing so was informed both by the emerging categories from the data and by the literature. In particular, there is a gap in the literature on the role of the administration personnel in MM care and their

interactions with care providers (Section 2.3). The theoretical framework in this paper (Section 2.2) assumed that coordination and workflow activities from the administration and study nurses provide general scaffolding for care providers in their interactions with patients and care delivery.

On the basis of this analysis, we developed a framework of uncertainty increase and reduction in MM care.

4. RESULTS

The results first identify four uncertainty increasing and uncertainty reducing factors for all complexity types. *Space Clusters* and *Prospective Abstraction* increase uncertainty while *Retrospective-Reconstructed Future* and *Similar Staring Points-Different Trajectories Pathway* reduce uncertainty. In terms of complexity typologies, non-clinical actors provide both provide stable and unstable conditions for care providers to act upon. Stable conditions are represented by pre-defined parameters in documentation while unstable conditions refer to a dichotomy between what is written and the format in which it is written. Unstable conditions cause progressive information attrition, which in turn forces care providers to develop ad hoc empirical strategies for a limited time. We give more detailed information on these processes bellow.

4.1 External Uncertainty Factors

** *Appendix A includes examples with quotes* **

(a) *Space Clusters*

The experts consulted perceive uncertainty in terms of interactions between material space, organisation, function and technology. Our respondents see space clusters as both a compartmentalisation of knowledge (each space of the infrastructure is devoted to a particular task) and a link between healthcare practitioners from different disciplines. Physical infrastructure becomes a precondition for working together across specialisations. Collaboration between different healthcare practitioners is thus spatially and locally enforced (i.e. departments are designed to be close to each other).

The *Space Clusters* factor amplifies and increases uncertainty. Namely, in terms of relative ignorance, intentionality for space clusters is high because as the healthcare experts note, there is nor guarantee that people will collaborate despite such space arrangements.

(b) *Retrospective – Reconstructed Future*

According to our respondents, solving care complexity depends on (i) a retrospective division of the problem into different parts (e.g. tracking different and existing work practices) (ii) references to existing resources and (iii) projections in the future as to how solutions can be applied. The goal is to develop a solution that will be both relevant for current problems and consistent in the future.

The *Retrospective-Reconstructed Future* factor reduced uncertainty. Namely, the intentionality is quite low: if healthcare providers fail to align timeframes, it is not because they do not want to, but because they do not yet have a correct representation of the existing resources. Temporality is moderately high: healthcare providers are likely to quickly develop solutions for current problems, but they will need more time to develop solutions that will be consistent in the future as well.

(c) *Prospective Abstraction*

For organization and communication between departments, our respondents note that they have to engage in prospective abstraction. Namely, healthcare providers start with very specific and concrete information (e.g. medication, specific ideas for department reorganization), but the coherent integration of all these different components from different people and across departments can only be made through abstraction (e.g. a general procedure protocol for the hospital network use). Abstractions of such kinds are based on the evaluation of future prospects: the focus is not on how abstracted solutions to complexity and uncertainty could be solved now, but how they can be applied in the future.

The *prospective abstraction* factor amplifies and increases uncertainty. Namely, intentionality is high, as healthcare providers may feel some unease in providing highly abstracted solutions (this is seen as contrary to the ethos of evidence-based medicine that focuses on specific solutions) (Turabian, 2017) Temporality is also low, as criteria for abstraction of complexity,

communication and interactions can occur only after a relatively long period of time (Marcum, 2017)

(d) *Similar starting points – Different patient trajectories pathways*

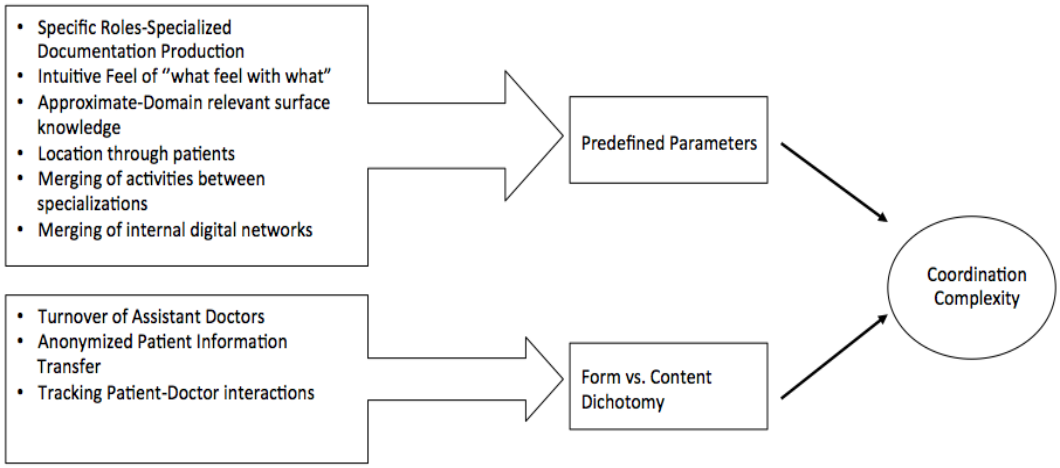
Healthcare experts note that although patients can have similar configurations of conditions, their trajectories may have different pathways with regard to the treatments, evolution of conditions and interactions with specialists within departments. Our respondents attribute this to a range of factors including the types of diseases concerned, patients' preferences and values, patients' general health before hospitalization, care configurations and the existing resources of the care delivery teams.

The *Similar starting points – Different patient trajectory pathways* factor reduces uncertainty. This is because temporality is relatively high: patients' pathways generally become clearer once the care scheme has been implemented.

4.2) Administration and Study Nurses: Coordination and Workflow Complexities-Zone availability for actions

* Appendix B includes categories and quotes **

Graph 2: Categories Structure Coordination Complexity and Zones Availability for Actions



4.2.1 Coordination Complexity- Goal Attainment State:

(a) ***Predefined Parameters***

The starting point in coordination activities is pre-defined. Non-clinical healthcare actors describe specialised roles for specialised and context specific document production. For instance, the secretariat personnel describes how certain types of documents are related to specific types of action and roles:

If I have a report from a patient who is suffering from HIV, then there are additional documents which I have to print out to send along with the report. But if it's a patient who needs a follow-up with an infectiologist, I just have to write the report and then it's done. (E 1)

As our participants suggest, such established templates allow us to produce relevant documents without a direct understanding of the matters at hand. In this sense, coordination through documentary means can occur without much prior or domain relevant knowledge. However, for the respondents, this lack of domain knowledge is compensated by an intuitive "feel" of the relevant context. This intuitive feel helps to differentiate between correct and incorrect information:

We really only have insight into what we write…. Sometimes when I write a word, I have the feeling that somehow it doesn't fit into the context. Or for instance, I have a report in which the doctor dictates a long sentence and somehow I think there's something wrong with the sentence (E 4)

In similar terms, study nurses do not derive any directly relevant knowledge about the issue at hand. Namely, study nurses state that they do not necessarily learn much in terms of how studies are conducted even if they are the ones who are administrating them in the first place: *I'm not necessarily learning anything in study management, but I might learn something about the drug or certain side effects.* (D 5)

In general, the administration staff rely on approximate, surface level knowledge of ''what fits with what'' in order to correctly locate the right information in the right place (for instance, where information can be found in the common IPEDOS network system).

However, knowing where information can be found does not only depend on where the information is stored, it can be also determined by the type of coordination relationships between department members. For instance, participants describe how they rely on patients to guide them through coordination activities with other departments. Participants associate this ‘’patient-guided’’ coordination to a general merging of activities between professional groups:

We always have someone from the medical side talking to us and to the nursing director. This means that we have actually united three professional groups for one goal…Somehow every process is interlinked, and the thread is actually the patient. He goes from administration, to the doctor, to nursing and again, to the administration. And everyone gets to see the patient's movements, steps and actions… We have tried to make work routes (between the patients and the professional groups) and work steps easier, better and more compact. (H 1)

This merging of coordination activities for different professional groups is also implemented in the merging of hospitals network (such as the IPEDOS network) that can be modified and accessed by healthcare practitioners inside and outside of the hospital:

That it's like a network that everyone can access, that everyone can take important notes within it. Now with the merger of the hospital network, different hospitals belong together to the (same) hospital group. And now you can connect to the (general) network, take out the data and continue working right away. They don't have to ask us for all the documents first, but instead, can access them themselves. (E1)

(b) *Form vs. Content Dichotomy*

Our respondents outline an opposition between the form of communication/documents for coordination and their content. Namely, they are responsible for the form, but not for the content of these communications (content is determined by doctors):

The information of the report is up to the doctor. What we are more responsible for is the appearance of the report. (E1)

According to the respondents, this content-form dichotomy results in a progressive disappearance of coordination information even if the form (e.g. the report) is still there. Namely, information about coordination is no longer retained because there is no information about specific relationships between patients and doctors. Participants attribute this to the increased rates of admissions for patients and the extensions of network systems that allow them to take more patients calls.

The information about doctor-patient relationships does not disappear (i.e. the reports still exist), but it is no longer traceable. However, the instinctive feel (cf. Section 4.2.1) of what belongs to what remains and compensates missing information about patients pathways in the department. Participants note that while the communication forms and outputs are retained in a physical form (i.e. printed documents, logs, reports etc.), they are often discarded over time, as their content is no longer relevant or even necessary:

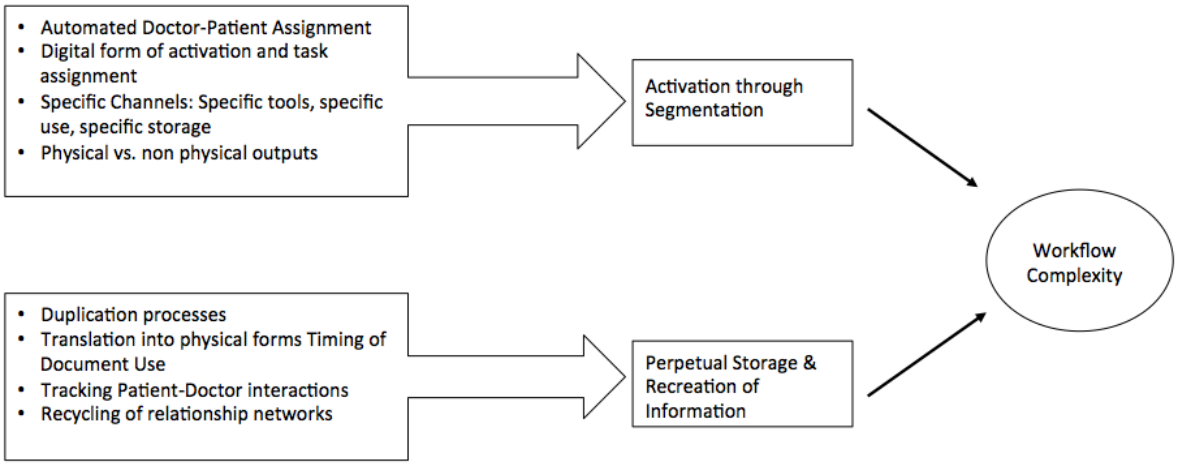
Before it was just, every patient stayed with the doctor and you could say, ah, that was this patient. Now, you just work on one (patient) and five minutes later you don't remember who it was. The words, you always write them, but it's not so important anymore, you don't keep it anymore. You don't know what it is exactly, you just know that it belongs to it. But then you can't explain how it was in the beginning. (E 3)

For study nurses, patient information is also either blurred or abstracted because it has to be anonymized for centralized transfer. The main coordination and collaboration function therefore is to link different locations and spaces. The patient is not a focus of coordination: the study nurse with the linking role does not know the patients whose data she/he transmits to various locations. Thus, linking and monitoring patient's data for the study across different sites occurs through anonymised, remote and abstracted elements of the patient (e.g. anonymized paper list):

I have nothing to do with the patients. I have a head office in London and I have different sites in Geneva and Zurich and Basel and here in Bern and I'm always the contact person. If there are reports that patients have some kind of event, then I pass it on to London. But I never see the patients and I am not involved in their care. I just see it on paper and anonymously. So I am really just the link actually. (D 5)

4.2.2) Workflow Complexity – Availability of zones for actions

Graph 3: Categories Structure Workflow Complexity and Zones Availability for Actions



(a) ***Activation and Tracking though segmentation***

Members of the administration state that platforms such as IPEDOS, Polypoint and SAP allow them to both distribute and track tasks by determining which doctor is associated with which patient. This is significant in two respects: first, the tracking of tasks (and the continuity of the workflow) is determined by systematic dyads between doctors and patients. Second, it also marks a change in the ways in which the workflow is activated. Participants describe that prior to the establishment of these digital platforms, the assignment of patients to doctors was made by the doctors themselves. Networks such as IPEDOS allow an impersonal, digital form of activation through the beeper (as connected to the network). Doctors are thus first assigned to patients digitally, but are then part of a ‘’physical’’ doctor-patient dyad later on:

There is a search number that runs through the beeper, that reaches the central office. The central office then receives a telephone from the family doctor, who then forwards it to us. Then we take the call and ask first whether it is a consilium or not. Then when I need (to find) the doctor, I can pass it on right away (to the doctor). Because it's usually true that (a) patient is usually with the same doctor so we look which doctor the patient has. (E 1)

As we have seen in Section 4.2.1 in relation to coordination, the respondents need specific tools to coordinate between departments and initiate collaboration. The secretariat for

instance, is directly responsible to the internal hospital network (IPDOS) and has access to the Swiss and cantonal networks (Phoenix). Platforms such as IPDOS are used to store patient files and reports (including the treating doctor, the interventions, and the location of the patient). This results in workflow segmentation: participants explain that their work and collaboration activities (and hence their workflow) are activated because specific tools have to be used in a specific, selective way, with a specific kind of storage:

For (consilium reports), we simply feed history entries into IPDOS. We don't have to write envelopes. It simply remains in IPDOS, in the form of a relatively short paper. And then there are the ambulatory reports, where we still need a problem list that has to be corrected and the laboratory (results) have to be printed out, because they are always sent with the report. Envelopes have to be written down, everything has to be put in a folder. …We have to give it to the doctor, who then gives it to the senior physician and then back to us to send it. (E 3)

Thus participants note that this selectivity and specificity of the workflow results in two main routes for workflow outputs. The first route means that outputs are not necessarily physical (i.e. administration members do not need to print and send them), while the second route results in very specific documentation types with specific sharing routes (i.e. reports are written and classified in specific folders for doctors).

(b) ***Perpetual Storage and Re-creation of Information***

For coordination issues (cf. Section 4.1) participants tend to refer to an automatic and progressive loss of information. For workflow issues, however, the respondents from the administration sector describe how information systems and storage arrangements guarantee a constant re-creation, reconstruction and storage of information. Participants say that they duplicate reports, documents and research arrangements in physical form by translating encounters into a physical, paper-supported format in the starting phases of the workflow: *During site initiation, we sit together and there is usually a doctor with us. And from then on we start planning, we have an electronic file, we have all the papers in it, we file everything, we have everything in paper form. And we always try to do it in double arrangements, that is to say that two people are responsible for the study (D 7)*

Administrative members state that a segmentation of the workflow in general and the workflow environment in particular allow them both to highlight routines actions (such as the tracing of patients) and to preserve them from suppression. No information can really be lost (in contrast to 4.1b in the coordination section):

I can't break anything if something bad happens or if something else is deleted by inadvertently. That you don't despair, that the (information) can be looked up or re-created. We try to depict our environment as well as to divide it into single individual parts so that we can think about what the patient or the employee does and at which moment. So nothing gets lost or forgotten. (H 1)

For study nurses, information cannot really be lost because it is enforced by stable relationship networks that can be applied to other situations:

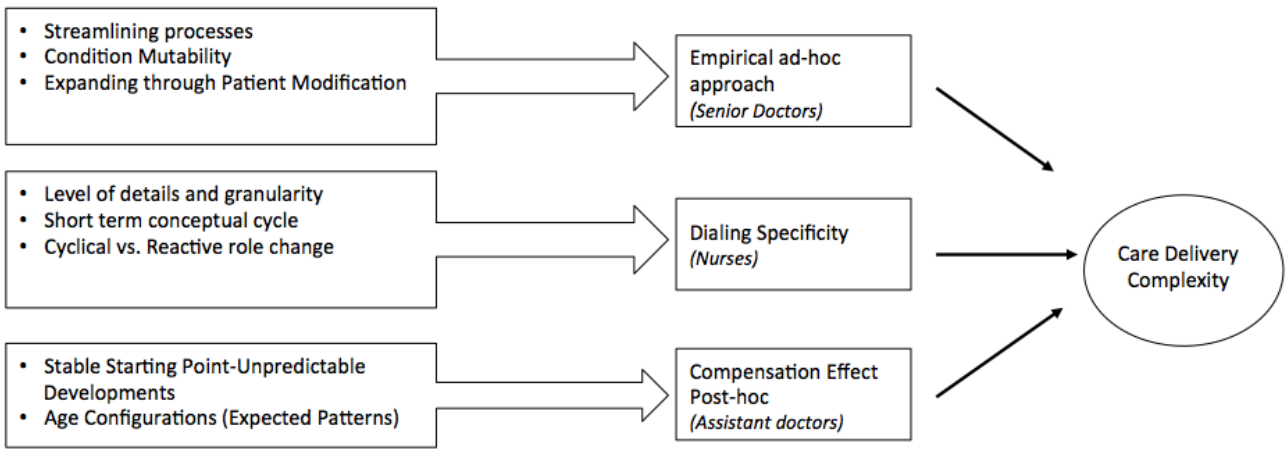
You can use these relationships for many different studies. You get a little bit into this HIV infectiological world. And they are then always the same names. And then you notice, ah, I have already talked to this doctor, I have also talked to this study nurse, and so it is much easier for other studies as soon as you are a little bit networked. (D 5)

4.3) Care Providers: Care Delivery and Patient-related Complexities

* Appendix C includes categories and quotes *

4.3.1 Care Delivery Complexity – Doctor Patient Perception Alignment

Graph 4: Structure Categories Care Delivery



a) ***Senior Doctors: Empirical ad-hoc approach***

Care decisions are usually calibrated in function of the results, but results are not available immediately. In such cases, doctors explain that they rely on an ‘’empirical therapy’’ strategy where all approximate factors (that is, those that are considered to be the most probable) are covered first. There is thus a choice between a streamlined approach (targeted treatment option on the basis of results) and a partially streamlined approach (approximate treatment option on the basis of most probable factors):

*The empirical approach says: the first thing is that we want to make some diagnostics before we have the full results of all the investigations. We will then have to give a so-called empirical therapy to cover all eventualities or the most probable infectious disease agents. And next tim*e *I see (the patient), I'll already have more complete information, which will help me to propose a definitive treatment plan. We will then adopt either a completely streamlined or a partially streamlined secondary approach.* (G4)

b) ***Assistant Doctors: Compensation Post Hoc Effect***

As assistant doctors note, some diseases are ambiguous in terms of development and effect: they can be active while still not presenting any particular issues. However, just because they do present normal results at a particular point in time, does not mean that they will remain unproblematic. Senior doctors note that these conditions are fluctuating in a way that could not be predicted and in relation to factors that remain unknown. Assistant doctors regularly control for any changes, even if these changes can be only made "post hoc" (there cannot be any monitoring of change in real time):

With hepatitis B, it's very complex because you have an infection in the liver, it's active but it's not causing any problems...We decided to do it around one year to be sure that the liver values are not moving. Because sometimes you say, ah but today it's very good, no problem, my patient is well. And if you undertake the same control one month afterwards, it's very high because it's just fluctuating. (B 7)

Assistant doctors make a difference between simple and complex situation configurations. In simple configurations, the number of diseases is ‘’compensated’’ by their lack of activity and the possibility of a straightforward treatment (which includes the possibility of control on further developments of the disease). In complex situation configurations, a disease (or one of the diseases within the conditions pattern of multimorbidity) is active and operating because the drugs and the treatment strategy adopted did not have an impact on it. As a result of this lack of compensation effect, the patient has to take more medications, which, in turn, means that more risky and complex treatment procedures have to be adopted. This, in turn, requires more input and help from specialists. A single disease can thus already create care delivery complexity:

The problem is when any of the diseases that compose the problems of the patient somehow decompensate. If a patient has diabetes, HIV, hypertension, heart problems, but none of these diseases are currently active and they are all under control with whatever strategies have been taken, then although the patient might be multimorbid, it is not a highly complex situation to deal with. When, for example, because of the many medications the patient might be taking, we will have to deviate from what are the simplest or less risky procedures, then we reach a complex situation where I'll need the help of other specialists. (B 6)

c) *Nurses: Dialling Specificity*

Nurses state that they begin their care delivery procedures by generating a general picture of the patient in the initial stages. The interaction differs significantly depending on the patient's knowledge level about his/her condition(s):

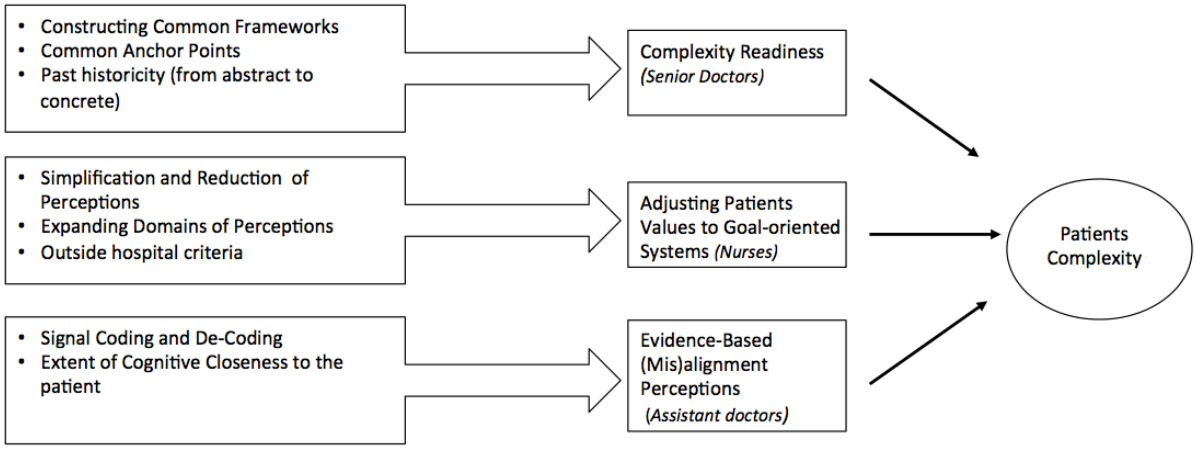
With someone who has been just diagnosed, I have to communicate in such a way that I am sure he has understood what he has. Then I communicate on a different level. I'll ask specific questions to someone who has had an illness for a long time. For instance, So ‘’what's your HbA1c? Then he can reply without further ado because he's already on another level. And the questions to me are more specific or go into much more detail. (C 6)

Nurses thus define their care delivery in interactions with the patients. Our respondents describe how they first manage and create shared provisory problem definition with patients according to various modes and levels (which run from general to specific). When a patient already has extensive knowledge, the level of communication and shared problem definition becomes specific and explicit. The problem definition in such cases is tailored only to a

particular patient. By contrast, when the patient has just received his/her diagnosis, our respondents define a problem in a very general way that can be understood by the patients.

4.3.2) Patient Complexity-Moments of Complexity

Graph 5: Structure Categories Patient Complexity



a) Senior Doctors: Patient Complexity Readiness - Diagnostic Algorithm

Senior doctors describe how their diagnostic strategies change in relation to complex and simple cases. If the cases are not complex, the diagnosis is already clear in a short period of time. In complex cases however, test methods reveal problems a posteriori, which generates exploration and discussions regarding the definitions of the conditions and their treatments. As a result, what changes with complex cases is the initial *diagnostic algorithm*: it cannot be used to predict how these conditions will evolve in the future because non-medical factors are also involved:

You do a brain MRI and you see it's a brain abscess. Then you'll have to do a brain biopsy to see if it's brain abscess or if it is a cancer. Then your diagnostic algorithm is completely different depending on the first evaluation. But when you start a treatment, then you get into complexity readiness, that is to say, if the patient is ready to be treated, if he really does want the treatment, if he will take his drugs, etc. So the medical aspect becomes less urgent and problematic, it's more the psychosocial network that is problematic. (I 1)

Thus as senior doctors describe, changes in diagnostic algorithms lead to complexity readiness. Complexity readiness relates exclusively to the patient and covers the

psychological, social and familial issues (as opposed to purely medical issues) that he patient faces during his treatment. For senior doctors, complexity derives from the fact that the patients may not be ready for the psychological, motivational and social implications that the "diagnosis algorithm" entails.

(b) ***Assistant Doctors: Evidence Based (Mis)alignment of Perceptions***

The patient may have specific expectations and perceptions on what he/she thinks his/her condition is. As assistant doctors explain, if these perceptions and expectations are not met by the actual results of medical investigations, the patient may reject these results outright:

And they are absolutely certain there is some parasite somewhere in the body. And you make every investigation and there is nothing: the problem is because of a psychiatric disorder. It's difficult to say to somebody, "you don't have anything, you are healthy, just go to a psychiatrist"…The complexity comes from there, you are just not at the same level as the patient. You are thinking about something and your patient is thinking about something different and you don't find a way to (understand) him. (B7)

There are thus two opposing logics at work in this case: there is the medical, evidence and results based logic of the doctor on the one side, and the personal, subjective perception and experience on the patient side. There is no common framework of interpretation in such cases: the patient's expectations and perceptions regarding his/her illness cannot be integrated within an evidence-based medical framework.

(c) ***Nurses: Adjusting Patients' Values to Goal Oriented Care Systems***

Nurses state that patients have a knowledge which, on some occasions, can help them to develop a representation of what the condition is and what care is required. In such instances, the patients and nurses find a common ground for implementing and discussing care. Nurses also describe cases where a patient's logics and beliefs are in direct opposition to the goal and principles of the care system of which they are a part:
So there is a married couple and they have three children and they are both HIV positive. The husband says "there is no HIV; this disease does not exist''. And he refuses to take medication, he refuses to acknowledge the diagnosis and he refuses to authorize any therapy

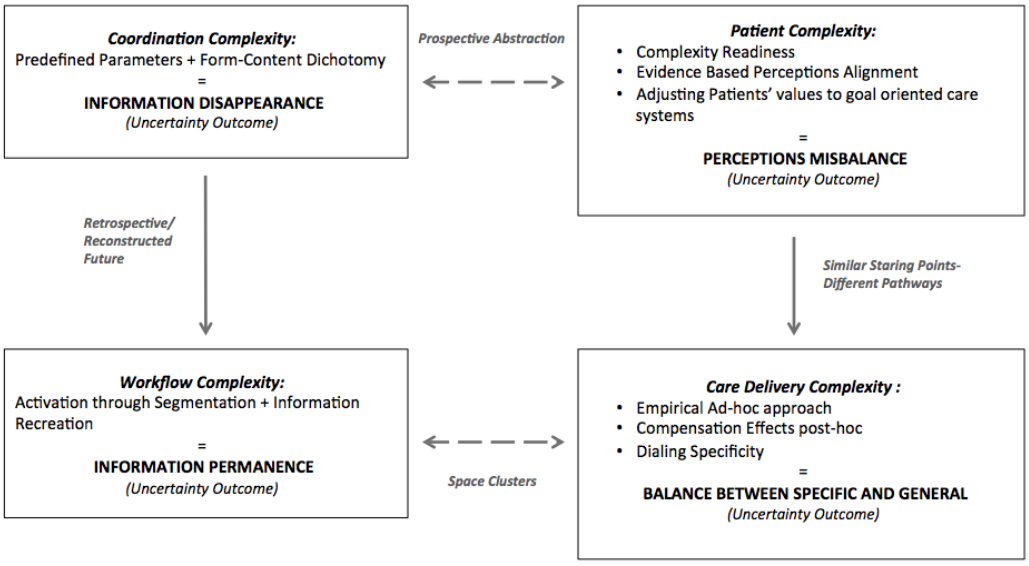
to his wife. And he has so much power on her that she is also not allowed to take therapy. (C 9)

Nurses also state that once the patient is in his/her home habitat, different rules and different criteria for complexity and illness apply. Nurses explain that they do not have the resources to determine and deal with these new criteria and the non-compliance that usually comes with it (e.g. the patient refuses to take medication when at home). The only solution that remains is to try to integrate the patients (and the cultural and social system they bring with themselves) into the care system of the hospital. This can be achieved only by going outside the role required and by taking additional responsibility that go beyond professional oriented time (e.g. conversations and advice given in free time). Bringing in other specialists (e.g. doctors) from the hospital does not help:

I have been trying for years to get him to take these medicines when he is at home so that he will learn to take these medicines independently. It has never worked. The infectiologists and doctors said we cannot do it anymore. There was never any compliance. In the end, they just kept trying to get him to work a little better in the system. And I spent a lot of time talking with him and advising him in my free time. (C 2)

5. MODEL

Graph 6: Model of Uncertainty Increase and Reduction for Administration practitioners and Care Providers



5.1 Uncertainty Increases through Prospective Abstraction

(a) *Coordination complexity results in Patient-related uncertainty: From Disappearance of Information to Perceptions Misbalance*

The coordination provided by the administration and study nurse staff of the hospital is articulated around (*i*) predefined parameters and (*ii*) dichotomy between the form of information and its content. Both of these dimensions result in a *progressive disappearance* of information with regards to reports, patient-doctors assignments and registrations. This progressive disappearance is compensated by the constant storage and generation of information during workflow activities.

Coordination from the administrative and study nurses staff provides both a fragile (e.g. progressive information loss) and a stable (e.g. predefined parameters) background for the healthcare team. As a result, nurses, assistant doctors and senior doctors all experience a *perception misbalance* in relation to the patients to different degrees. While this misbalance is often compensated over time (cf. through care delivery strategies), it does not fully disappear as any external perturbations (e.g. event outside the hospital) can create misbalance in unexpected ways.

In the present model, *prospective abstraction* is a process that increases uncertainty and thus links coordination complexity to patient's complexity. Namely, the coordination processes (as implemented by the administration and study research staff) relies on highly abstracted and predefined parameters (e.g. insurance reports, formats within the IPEDOS files). These abstracted, predefined parameters of communication and knowledge production are used to evaluate the future prospects of doctor-patient interactions (e.g. patient-doctor dyads as orientation cf. 4.2.a).

However, the uncertainty, especially in relation to patients' complexity increases: prospective abstraction within healthcare interactions and treatment schemes (as expressed by form and content dichotomy) makes it difficult to integrate specific patients' perceptions and experiences into the general, medical care framework in the hospital. Above all, because of abstraction, changes in patients treatment readiness cannot be predicted and tracked.

Prospective abstraction processes in coordination thus produce relative ignorance (and thus uncertainty) about patients complexity on the intentionality axis. Namely, the progressive disappearance of information during coordination activities creates low intentionality: because of prospective abstraction, healthcare providers may simply not know about their patient's subjective experience.

5.2 Uncertainty Increases through Space Clusters

(a) *Workflow Complexity results in Care Delivery Uncertainty: From Information Permanence to Balance between Specific and General*

In the present model, space clusters increase complexity between workflow complexity and care delivery complexity. As we noted in Section 4.1, space clusters represent both a compartmentalisation of knowledge (each space of the infrastructure is devoted to a particular task) and a link between healthcare practitioners from different disciplines.

The activation and tracking of doctor-patient interactions through segmentation and specification of the workflow pathways correspond to space clusters: the workflow is structured in terms of different (but adjacent) locations, where different specialists operate with different tools (e.g. reports, laboratory results). Because all agents are involved in this specification (the administrative staff, the nurses, senior doctors etc.), they leave traces of their actions that are available to all (e.g. reports, protocols). As a result, healthcare practitioners have an implicit ''feel'' of where the right information is, even if explicit protocols for knowledge locations are not always clear (e.g. difficulties in finding relevant link details in the IPEDOS file). This intuitive knowledge of ''what belongs to what'' allows locations in the workflow that merge different specialities together (e.g. site initiation where both study nurses and doctors are present).

Space clusters in workflows increases uncertainty in care delivery because they increase the options for the ways in which treatments can be interpreted, transmitted and delivered. More concretely, care delivery teams (such as doctors, assistant doctors and nurses) have to take in account the fact that results (on which further treatments are based) are available only after a relative period of time. In order to administer care and give treatment in the absence of definitive results, healthcare providers streamline options (e.g. by excluding the most

improbable factors) or offer initially generalized explanations (e.g. nurse explain care delivery to patients in general terms). While this approach allows us to continuously refine care delivery as time goes by, it also exclude potentially valuable details from the onset, as they do not correspond to the expected disease framework. In this context, mutable conditions (i.e. conditions that remain dormant, but can become active later) are unpredictable as neither their onset nor their treatment pathway can be predicted.

On the administration level, healthcare practitioners see workflow as a process that guarantees the permanence of information. Because of the infrastructural characteristics (e.g. internal digital networks), duplication processes and the constant conversions of interactions into ‘’physical’’ formats, no information can truly be lost. For the administration and the study nurse staff the workflow is activated though the segmentation of the workflow: specific tools (e.g. ambulatory reports) have to be used in specific ways so that other members of the care team can participate.

The segmentation (and thus the activation) of the workflow by the administrative and study nurse staff thus creates scaling opportunities for care delivery. Namely, care providers in this study have to constantly re-interpret and modulate the links between the specific (e.g. when a condition becomes ‘’active’’ and had to be treated immediately) and the general (e.g. the general pattern according to which conditions are expected to develop). The aim is to create a coherent, robust balance between the general and the particular in care delivery: any changes will include adjustments and compensation in care delivery conditions (such as adjusting the patient’s knowledge levels or partial streamlining of treatment options or compensation strategies for active conditions). The balance, however, is fragile, because the temporality is high: healthcare providers become quickly aware of the segmentation of the workflow (who does what and how) which, in turn, limits the flexibility in adjustments for care delivery.

5.3 Uncertainty Reduction through Retrospective-Reconstructed Future

(a) *Coordination complexity reduces workflow uncertainty: From information disappearance to information permanence*

In this model, coordination complexity is linked to workflow complexity through *retrospective-reconstructed future* processes. These processes refer to the practice of

generating future-oriented solutions on the basis of (i) a retrospective re-evaluation of past and current problems (ii) past and existing resources. In summary, retrospective-reconstructed future processes allows us to construct the future with elements from the past. The future is also ‘’reconstructed’’ (rather than simply constructed) because it merges different timeframes of actions and perceptions from the past across specializations and across patients into a coherent whole. Workflow complexity (i.e. that in this model results in information permanence) thus reduces uncertainty in care delivery because the intentionality to *not* know is very low (no information can be truly lost), while temporality is high (healthcare providers state that their use of streamlining techniques, such as the empirical ad hoc approach, occur over a short period of time).

As we have seen, coordination complexity is perceived in terms of pre-set parameters and content-form dichotomies that, in turn, result in a progressive loss of information. In this model, the process of *retrospective-reconstructed future* uses these features of coordination complexity to reduce workflow complexity, that is to say, *retrospective-reconstructed future* highlights pre-set coordination parameters in order to open future possibilities for activation and tracking in the workflow.

Namely, the fact that coordination is already structured by pre-determined, specific parameters allows us to project targeted segmentation and specification of workflows in the future so that all agents (i.e. all care delivery providers) can take part. Care delivery providers all have different timelines of actions and tasks across specialisation. However, by executing their actions in the same workflow under pre-defined parameters and sectors, they will ensure that all their different timelines will be merged into a coherent workflow in the future. In the model therefore, there is a correspondence between the predefined parameters in coordination and the activation through the segmentation and specification of workflow.

Paradoxically, retrospective-reconstructed future processes also allow us to understand how the progressive disappearance of information in coordination flows can be translated into permanence of information in workflows. The form-content dichotomy is the result of a misalignment of timelines, perception and knowledge differences (e.g. the secretariat staff does not have the same insight into the reports as doctors). However, before the information disappears, both the secretariat staff and the doctors have the time to leave fleeting traces in

the workflow (e.g. reports) that can be taken over by other care provider members of the department.

This is where retrospective-reconstructed future processes are important: when traces are too faint for others to take action, they can still be reconstructed by turning back to the segmentation and specific channels of the workflow (e.g. admissions are distributed through the beeper before being passed on to the secretariat and then to the doctors—even if the information is no longer there or useful). The reconstruction of what happened through pre-established channels becomes itself a trace for future actions by other workflow members.

5.4 Uncertainty Reduction through Similar starting points-Different trajectory pathways factor

(a) *Patient complexity reduces care delivery uncertainty: From misbalance of perceptions to balance in care delivery*

This model links patient complexity with care delivery complexity. This occurs through the particularities and differences of *patient trajectory pathways*. As we have seen in Section 4.1, patients may have similar starting points at the beginning of the care interaction, but end up with different trajectories and outcomes. In the model, the patient trajectory pathways factor reduces complexity in the care delivery. As we have seen in Section 4.3, a misbalance between healthcare providers medical framework and the patient's perceptions and subjectivities characterizes patients complexity. While healthcare providers have many strategies for mitigating this misbalance, any solution remains firmly within the medical framework. The *patient trajectory pathways* factor shows how this misbalance is transformed into a balance between the general and the particular in care delivery.

According to the *patient trajectory pathways* factor, patients have similar starting points exclusively within the medical domain: they may have similar patterns of conditions and similar disease antecedents. The subjective, social and behavioural state of the patient at the start of the care intervention is never similar to others as all patients are unique. At the beginning, therefore, the subjective and the medical domains are separated. It is only as the care relationship goes on over time that the two domains begin to interact. Our respondents, for instance, note that the patient's medical compliance over time is influenced by personal

factors such family arrangements, social situations and perceptions developed of the course of the treatment.

The misbalance between the patient's perceptions and healthcare providers medical frameworks can be explained by this initial separation between the medical domain and the subjective domain. Once the treatment, the medical and the subjective domain begin to interact, healthcare providers are left with various strategies for either increasing or decreasing the specificity of the treatment in relation to patient. Balance between the general and the specific in care delivery is thus achieved in spite of the misbalance between the patient's and his/her doctor's perceptions, but rather because of it. It is the potentially similar medical starting point of the treatment interaction that gives the necessary background for balancing the medical framework of healthcare providers and the experiential framework of the patients.

Uncertainty in care delivery is thus reduced because the patient's related complexity induces relatively high levels of intentionality (i.e. if healthcare providers are not able to integrate the patient's perceptions into their care, it is because doing so will damage the care scheme in general) while temporality is high (healthcare providers learn very rapidly which adjusting, balancing methods are available in care delivery).

6. Discussion and Conclusion

In the present paper, we aimed to explore healthcare provider perceptions of complexity and uncertainty in multimorbidity care. In doing so, we relied on two distinct theories, namely, non-linear complex adaptive systems on the one hand, and relative ignorance literature on the other hand. We assume that these theoretical domains are complementary. Namely, CAS theories (such as stigmergy and chaos theory) are not directly applicable to human healthcare actors, because they cannot account for individual intentionality (Turabian, 2018). We mitigate this limitation by adding the notion of relative ignorance where individuals differ on the intentionality and temporality dimensions.

6.1. Perceptions of uncertainty: Correspondence with Stigmergy and Chaos theory

Our model shows that perceptions of complexity and uncertainty can be framed through stigmergy and chaos theories. Reliance on CAS theories allows us to understand the

relationship between those healthcare practitioners who have contact with patients and those who do not.

Namely, the secretariat, reception and study nurse respondents fail to provide traces upon which healthcare providers (such as senior doctors, assistant doctors and nurses) can act. As we have seen in Section 4.2, the secretariat staff feels that information disappears gradually during coordination activities. However, the secretariat and reception staff, as well as study nurses, provide an environment where healthcare providers (who are in contact with patients) can act and thus leave traces themselves.

In stigmergy terms, uncertainty is thus defined by contradictory (but complementary) coordination and workflow activities from agents with no contact with the patients or care delivery per se (e.g. the secretariat). Namely, non-clinical actors and members from the administration are not able to leave lasting traces for coordination (e.g. information in reports tends to disappear over time), but they provide a robust environment for workflow activities. Care provider participants (such as nurses and doctors) thus describe a particular form of relative ignorance (and thus of uncertainty): they may not know the details of some types of information, but they know where it can be located because specific workflows are related to specific tasks and pathways. In this sense, no information can be truly lost because it can be always traced to particular segments of the workflow. The administration staff leaves traces not through joint actions in the environment, but rather through the segmentation and specification of the environment.

Chaos theory applies to those healthcare practitioners who are in direct contact with patients and care delivery. Namely, non-clinical actors provide a scaffolding where doctors and nurses have an active, segmented workflow environment to work with, but no coordination traces. In chaos theory terms, this means that doctors and nurses can rely on active workflow parameters for their care delivery and interactions with patients (i.e. the ‘’who does what ’’ question) but they do not know why and when such workflow parameters can be activated.

Care delivery participants thus operate in highly sensitive initial conditions (Section 2.1). Namely, while the environment for care delivery and patient admission is firmly in place (Section 4.2.1), it is not clear which part of the workflow is activated by complexity and when (Sturmberg and Martin, 2020). For care delivery, care providers feel that they can either

deduce or approximate the timing and location of workflow activation in an empirical, rational manner. Over time, the knowledge of the patient changes as does the involvement and workflow of the nurses and doctors involved. Care delivery is thus characterised by balance and stable equilibrium: care providers adjust and monitor the possible development of conditions, the test results and the patient's information in order to establish a stable care delivery strategy.

By contrast, patient complexity involves (perceived) misbalance of the patient's subjective experience and the medical framework in which care providers operate. That is, it is no longer possible to deduce which part of the workflow may be concerned and activated by coordination activities. In this study, healthcare providers aspire to reach an equilibrium state of minimal potential energy with their patients (e.g. by aligning patients perceptions to theirs so that both patients and healthcare providers are "on the same page"). However, this equilibrium state is difficult to obtain: incremental feedback from the patients cannot fully reach care providers, as it is not compatible with the medical care framework. As a result, the initial conditions do not change: contradictions between the patient's perceptions and care requirements remain incompatible as the care relationship goes on.

6.2. Temporal and Intentional Dimensions of Uncertainty

For CAS literature, complexity refers to situations when healthcare practitioners agree on the outcome of a specific action, but do not have enough information to predict and plan common actions towards a goal (cf. Section 1). Pype et al. (2017) state that healthcare practitioners deal with such situations through experimentation, creativity and alternatives to routinized procedures. However, because in the present paper the focus is instead on uncertainty, healthcare practitioners do not necessarily need certainty and agreement for communication with each other. Instead, they need a background to leverage their knowledge gaps (i.e. how much they need to know something) against their intentionality (i.e. the extent they are willing to ignore specific information).

Our analysis reveals that knowledge gaps (i.e. temporality cf. Section 2) and intentionality are not the property of individuals, but of the healthcare specialities concerned. For instance, both the administration staff and the study nurses describe how they deliberately ignore certain types of information because it is either no longer used or unnecessary. Assistant doctors also

outline how their timing of knowing test results differs from the laboratory personnel. Each type of medical speciality has such individual variations on the temporality and intentionality domains for uncertainty.

Thus for each speciality, the core issue is to leverage the time it takes to know some type of information (i.e. temporality) and the extent to which information can be ignored (i.e. intentionality). This is done either through uncertainty-increasing or uncertainty-reducing factors. For the administration staff and study nurses for instance, the *Retrospective-Reconstructed Future* factor reduces uncertainty by turning information loss in coordination activities into perpetual information permanence in workflows (Section 5.3).

Namely, the retrospective re-evaluation of problems (c.f. Section 4.1b) requires a low intentionality of ignorance: people cannot consider information retrospectively if they do not want to. By contrast, a relatively considerable amount of time is necessary before future-oriented solutions can be known (low temporality). The *Retrospective-Reconstructed Future* processes thus identify where uncertainty lies for non-clinical healthcare actors. Namely, uncertainty refers to the time needed to fill in certain gaps on how coordination would look like in the future (hence the problem of tracking doctor-patients dyads over time). It is thus temporal uncertainty that is reduced and compensated in workflow activities because no information can truly be lost.

The multimorbidity literature sees complexity as an interplay of inter-related interdependencies. In this paper, however, healthcare practitioners understanding of complexity is only a step towards a more generalised interpretation of uncertainty. Uncertainty itself is not made of interdependencies, but of binary oppositions between different levels of relative ignorance both in terms of intentionality and in terms of knowledge temporality. These binary oppositions suggest that uncertainty in multimorbidity care, include the potential for its own resolution. In this context, perceptions of healthcare practitioners in this paper reveal where uncertainty in multimorbidity care is located and how multimorbidity care is shaped by interactions between those healthcare practitioners who provide care directly and those who do not.

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ESSAY 3 :

Health Care Providers' Experience and Perceptions of Patient Complexity:

An Observation Study in HIV Outpatient Clinical Practice

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Health Care Providers' Perceptions of Patient Complexity

An Observation Study in HIV Outpatient Clinical Practice

ABSTRACT

Patient complexity is an increasingly used concept in clinical practice, policy debates, and medical research. Yet the literature lacks a clear definition of its meaning and drivers from the health provider's perspective. This shortcoming is problematic for medical education in the light of a rising number of multimorbid patients and the necessity for future health care providers that are adequately trained in treating complex patients. Based on open-ended in-depth interviews with health care practitioners treating HIV patients in a hospital-based outpatient clinic for Infectious Diseases (ID), this study develops an empirically grounded framework of complexity-contributing factors and unpacks the relationship between health providers' experience and perception of care complexity. The framework conceptualizes case complexity drivers, the provider's perceived controllability, and a set of complexity moderators at the levels of the patient, the care provider, and the broader care context. The novel framework advances a shared understanding of the nature of patient complexity. By foregrounding the role of professional experience, it also helps to inform curriculum design and the teaching of essential skills to medical students in areas characterized by high patient complexity such as general internal medicine and geriatrics. From policy perspective, the findings have important implications for the design of more effective health care interventions for complex patients.

INTRODUCTION

Providing medical care for complex patients constitutes one of the most challenging aspects of modern healthcare systems. In clinical practice and the research literature, the concept "complex patient" typically refers to patients with coexisting chronic conditions (i.e. comorbidity, multimorbidity, polypathology, dual diagnosis) and challenges associated with managing interactions among various conditions and medications. Medical complexity—the number of comorbidities—poses well-known challenges for patients, health care professionals, and health care systems. Yet studies investigating complex patients show that while the degree of comorbidity is informative for gauging the degree to which physicians experience a patient as "complex", such measures do not fully capture complexity from the health provider's perspective.[1–6] Indeed, practitioners' understanding of complexity entail a much broader set of contributing factors, including the patient's psychosocial vulnerabilities, socioeconomic environment, cultural background, and behavioral factors.[2,5,7,8]

While the importance of incorporating a broad range of complexity contributing factors into research on complex patients is increasingly recognized, recent studies indicate that much remains to be understood about patient complexity in clinical settings. Indeed, an analysis of the health science literature between 2005 and 2015,[9] posit an urgent need for conceptual clarity about patient complexity and the ways in which medical practitioners experience it.

This study develops empirically grounded knowledge on how complexity-contributing factors of HIV patients translate into health care providers perceptions of care complexity in a hospital based outpatient clinic for Infectious Diseases (ID). Understanding the meaning, drivers, and outcomes of patient complexity from the health care provider's perspective and the role of experience in complexity perceptions is of significant practical relevance. In HIV clinical care, for example, advances in antiretroviral therapies, disease screening and health promotion have significantly improved the life expectancy of HIV-positive individuals.[10]

Consequently, age-related multimorbidity pose new, hence incompletely understood challenges for clinicians and health-care planners, challenges that require medical education, effective health care interventions, and organizational support systems.[8,11,12] For example, care for complex patients involves close coordination among specialists forming multidisciplinary teams. Ensuring that such teams achieve positive patient outcomes requires that care providers collectively understand the nature of patient complexity. From an education and policy perspective, developing a better concept of perceived complexity and the role of the practitioner's exerpience is critical for designing effective health care training and interventions that improve patient care while curbing the disproportional use of health care resources for complex patients.

To elaborate our understanding of care providers' complexity perceptions, we conducted a qualitative study based on open-ended in-depth interviews with health care practitioners with different levels of experience. Our data collection and analysis builds on a separation of two domains[1] of complexity in HIV clinical practice: (1) patient-related factors (case complexity), and (2) care delivery-related factors (care complexity).[7,13,14] To advance prior work, we explore under what conditions case complexity translates into perceived care complexity. Focusing on complexity perceptions among nurses, junior physicians, and senior physicians, we also address the paucity in research on differences in complexity perceptions among healthcare professions and among healthcare providers with different levels of experience.

Drawing on our findings, we propose a conceptual framework that outlines key relationships among complexity-contributing factors. The framework unpacks the medical professional's perception of care complexity by separating case complexity drivers, the provider's perceived controllability (i.e., the sense of his or her ability to diagnose and

[1] This conceptualiation reflects the separation of case complexity and care complexity (de Jonge et al., 2006; Doessing & Burau, 2015) on one hand, and the separation of patient complexity and clinical task complexity (Islam et al., 2016) on the other hand.

exercise control over the patient's health state), and a set of complexity moderators at the levels of the patient, the care provider, and the broader care context. Finally, we present ten key questions to help guide medical professionals in making complexity both more explicit and more manageable in daily practice. Our findings and framework help advance to notion of patient complexity for HIV clinical practice and future research into care complexity drivers.

METHODS

To develop understanding of health care providers' perceptions of patient complexity and the role of experience therein, we conducted a qualitative study of practitioners with varying levels of experience and across medical professions (i.e., junior and senior nurses and physicians). Within the qualitative paradigm, we conducted a phenomenological approach, so as to develop an in-depth understanding of patient complexity perceptions within the broader social context of the medical practitioner's work setting.[15-17] This approach allows the researcher the focus on practitioners' lived experiences with respect to patient complexity and the issues influencing the construction of individual perceptions of complexity. Interpretative phenomenological analysis (IPA) provided the general research framework for our data collection and data analysis process.[18-20] IPA foregrounds that the meanings that individuals attribute to their experiences can be accessed and understood through an interpretative process that focuses on the subject's individual cognitive inner world.

This study was designed and conducted with careful attention to ethical aspects, and in particular participant confidentiality. The study is exempt from ethics review board approval according to Swiss law. The data do not contain information about persons but about the processes in the health care services of the hospital. The records are anonymised. Therefore

these data collection does not come under the Data Protection Act nor under the Human Research Act.

Participants and Setting

We conducted a qualitative study using semi-structured interviews with nurses and junior and senior physicians of an ID department in a high-capacity Swiss university hospital, focusing on the department's HIV outpatient care activities. In collaboration with the clinic director, we scheduled interviews with all available department members, resulting in 31 participants, including 17 nurses, eight junior physicians, and six senior physicians.

Data Collection

To structure our interviews, we used an interview guide focusing on health care providers' perceptions of patient complexity in both multimorbid and non-multimorbid patients in general, with a focus on the department's activities in HIV clinical practice. In Phase 1 of our study, we developed our interview guide in two stages. In the first stage, two members of the research team, the principal investigator for this study (S.B.) and a research assistant (A.S.) conducted exploratory pilot interviews with department members, including nurses, junior physicians and senior physicians. Interviews lasted between 45-60 minutes. From these interviews and our analysis of the literature on complex patients, we developed an initial set of questions covering the health care provider's background and daily activities, perceptions of complexity, and practices and strategies used in treating complex patients. To refine our interview questions and ensure they were relevant to the research context, in the second stage, we conducted a round-table discussion with 12 department members.

Using the insights from phase 1, in phase 2 of the study, S.B. and A.S. conducted 31 semistructured interviews over a 6-month period. Participants were briefed on the purpose and confidentiality of the interviews, and were encouraged to share detailed personal experiences as much as possible. Interviews took place in physicians' offices or other private

spaces chosen by the interviewees. Interviews lasted around 60 minutes on average, and were digitally recorded and professionally transcribed verbatim.

Data Analysis

The final data consisted of 320 pages of single-spaced transcripts. Transcribed files were stored and thematically analysed in NVivo 11, a qualitative data analysis software (QSR International). We followed a systematic inductive procedure for analysing qualitative data.[21] First, all transcripts (raw data) were closely read multiple times by S.B. and A.S. During this stage, we discussed the meaning of interview segments to develop a coding frame that we then used to code all transcripts. We next discussed selected coded segments and refined the coding scheme in several rounds, after which the transcripts were recoded according to the new coding scheme. This inductive approach allowed for overarching general categories and more specific lower-level categories on complexity perceptions and relations among these categories to emerge from the data. We also identified differences and similarities in complexity perceptions across levels of experience.

From this initial analysis we developed a preliminary framework of the main domains and drivers of complexity perceptions among health care providers. In producing the final framework and reporting the study, S.B, A.S., and G.K. elicited and incorporated the perspectives of three participants (A.H., who is an attending physician in infectious diseases, A.R., who is a professor of infectious diseases, and H.F., who is head of department and professor of infectious diseases). The involvement of these participant-authors explicitly concerned discussions aimed at ensuring sensitivity to the research context and refining the emergent framework. At no point were participant-authors involved in data selection or analysis.

RESULTS

Figure 1 shows a conceptual framework of our key findings. Our analysis revealed how case complexity drivers and a set of complexity moderators at the patient level, care provider level, and care context level jointly determined care providers' perceived controllability—referring to the provider's sense of his or her ability to diagnose and exercise control over the patient's health state. Providers' perceived controllability, in turn, was a key driver of perceived care complexity. We next elaborate on these findings.

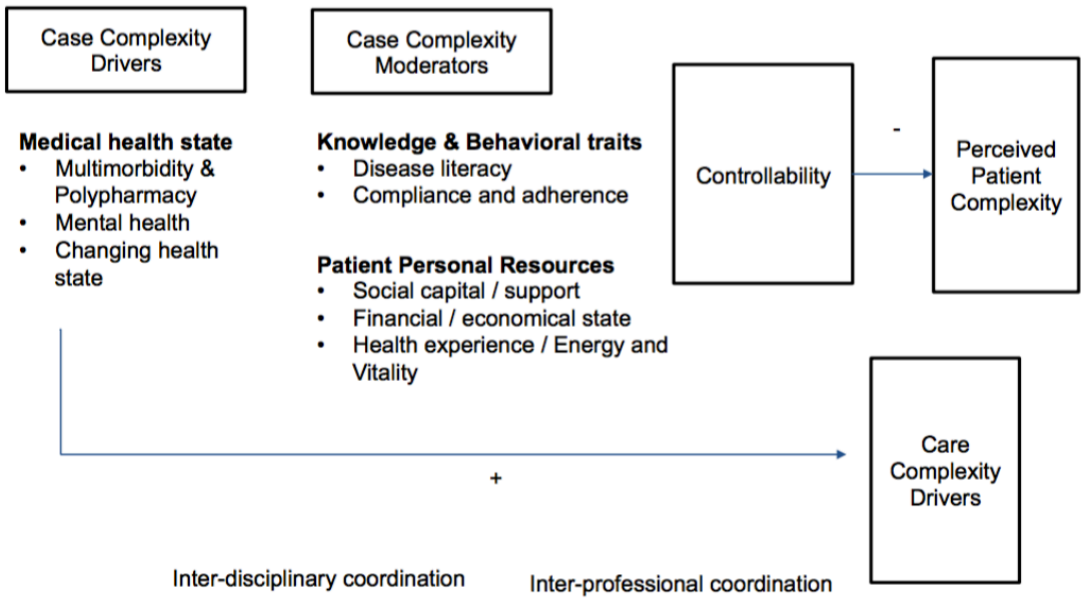

Figure 1 : *Model of Care Complexity Drivers and Case Complexity Moderators*

Case Complexity Drivers

Participants described complexity-contributing factors relating to the patient's medical health state as the primary component of case complexity. Factors in this category included multimorbidity and polypharmacy, mental health, and changes in the patient's health state.

Multimorbidity, polypharmacy, and instability

Participants identified the presence of multiple chronic medical conditions as a general driver of perceived patient complexity. As one junior physician explained:

> A simple situation would be a patient who needs his HIV drugs and takes them regularly and has no contraindication to receiving a single tablet regimen. A more complex situation, for example, would be an older patient with several unsuccessful treatments behind him. That means he will have a complex HIV treatment with maybe four, five tablets per day. Regimens that may cause complications with his kidneys or digestion or sleeping are common. And then because of his age, he may have developed other conditions, such as hypertension, which would formally have a contraindication for some HIV treatments. That means he is at risk of cardiovascular events, which we would have to check regularly with the cardiologist…. So complexity entails any situation where one of his problems would influence the treatment of other problems in a negative way, such that you cannot deal with every disease optimally. (B6)

When asked what makes multimorbidity cases complex, one senior physician explained:

> ...whenever one starts treating an aspect of the disease, it will immediately influence other aspects. So one creates new problems and enhance complexity because another problem will pop up…. That means that when treating multimorbid patients, one has to try to anticipate what will come next in order to not miss it. With non-multimorbid patients one doesn't have to do that as much. It's much easier and takes less effort. (G1)

Participants also discussed how polypharmacy posed challenges for controlling the patient's health state:

> Multimorbid patients often take a lot of other drugs. Clearly, there one has to be much more careful because of drug interactions. So the intern or I are going to spend some time on the internet platform on drug interactions in front of the patient and check if everything is okay…. That takes a bit more time. (G3)

> In older patients who have different conditions, many symptoms are generally caused by the drugs they are taking. Sometimes stopping or rearranging their drugs solves the problem. [But] it's difficult to spot the right moment to react. One cannot send multimorbid patients to the emergency ward every time they feel dizzy, that's not going to work…. Sometimes there is a risk of missing things because one's vision is blurred by all these other problems [that] might mask something more serious. (G3)

Moreover, participants argued that they would not perceive all multimorbid patients to be complex in care delivery:

> While a patient may be multimorbid, if none of the diseases are currently active but under control with whatever strategies, then it is not a highly complex situation. (B6)

Unstable or unexpected changes in patients' health conditions were another important source of complexity. As one nurse observed:

> Complexity also arises when something new is constantly coming up. A patient with a relatively simple treatment can suddenly develop hypertension, then a heart attack, then a hip surgery. None of these have to be difficult, but it becomes complex. (C1)

Mental health

Participants discussed various ways in which patients' mental health contributed to complexity, including factors such as anxiety and depression associated with the knowledge of living with a stigmatised chronic disease, and other psychiatric comorbidities. A senior physician gave the following example of the complexity involved in treating a HIV patient with a psychiatric disorder:

> In certain situations, patients with mental disorders go into risky behaviors that are harmful to them. We have a baseline HIV treatment, [but for these patients] I have to think about how to deal with the psychopathological condition, which may interfere with my treatment. Patients may stop taking pills and get sexually transmitted infections…. [For example], when one gets a hepatitis C infection…treatment is only possible when adherence is very good. So I [have to] make sure the patient has a really good psychiatrist, and keep close contact to discuss how our treatments interact. (I2)

Mental comorbidities can also drive complexity perceptions because they hamper diagnosis. As one junior physician stated:

> There are [multimorbid patients] that are very easy, and with whom it does not take a lot of time to know what the problem is. Then there are people who are so complex in their attitude. For example, patients who drink a lot may get very nervous and angry…and refuse to be examined. It can take more time to recognize other problems [in such situations]. (B1)

Provider's perceived controllability

Providers' perceived controllability entails a provider's sense of competence in providing patient care in a circumscribed situation. Participants noted that whether case complexity

drivers would indeed translate into perceived care complexity largely depended on the extent to which such drivers limited the provider's ability to diagnose, the scope of treatment options, and the ability to exercise control over the patient's health.

One senior physician discussed how multimorbidity can limit the ability to diagnose and determine the courses of intervention:

> When one suspects a lung infection in an otherwise healthy person, it's mostly just a simple bacterial pneumonia. But in a multimorbid person who has kidney dysfunction, heart dysfunction, and lung dysfunction and takes multiple medications, there are many more possible reasons for lung problems. So in multimorbid patients sometimes we initially don't know the etiology. We think we have to treat the pneumonia with antibiotics, but at the same time we have to improve the kidney and heart functions. And maybe even stop the drug they have to see whether it's an infection at all. The number of possibilities multiplies…. (G4)

Another senior physician explains how his sense of perceived complexity relates to his ability to influence the patient's health state:

> I would differentiate between the complexity which can be managed and the complexity which is very difficult to deal with. That is not necessarily dependent on the object of complexity. A situation can be very complex but quite easy to deal with if one has good interactions among the patient and physician and other important partners. [However,] if one has the problem that one cannot persuade the patient to take their drugs, that can be extremely difficult to manage. (I1)

In a similar vein, one nurse explained that:

> For me, something is complex when it is difficult to find a way forward. When everything has been tried, the situation doesn't improve, and one cannot change anything. (C1)

Complexity Moderators: Patient Level

Participants described a number of patient-related factors that enhanced or attenuated their ability to control complexity emerging from the patient's health state. These 'complexity moderators' included a patient's demographics, health objectives and behaviours, disease knowledge, and personal resources.

Demographics

Age

As is well known, age increases the likelihood of multimorbidity:

> Some MSMs have more sexual transmitted infections than other [patient groups]. That's something we can manage, we don't need other specialist for that…. Older patients are likely to have other problems that are not specific to HIV, like osteoporosis and high cholesterol. That's very normal but sometimes they also begin to develop forms of renal failure [or] high blood pressure…because of the HIV therapy. So we have to switch the therapy. (B7)

A senior physician explained how complexity in multimorbidity is becoming increasingly challenging in HIV clinical practice, as patients live longer due to improved therapies:

> A somewhat new field for us is that we now have patients who basically live as long as patients without an HIV infection. So we have an increasing number of older patients, seventy, eighty years old, who also have many other problems…. It's not only about more pathologies and more drugs but also about psychological and social things that one wouldn't do for a young patient. Older people have trouble taking all their drugs at the right time. So one has to work more with the nurses to prepare the drugs. Providing care in a more holistic way, not only for one's specialty and the other diseases but also the family and social context is important in these patients. (G3)

Age was also associated with patients' ability to curtail a spiral of illnesses. As one nurse noted:

> With older people, loneliness at home tends to come with bad nutrition, bad skin care, not drinking enough…. They take their medicine thinking: 'today the pink one and tomorrow the blue one,' more or less. Such combinations mean that people are sometimes in a very dire state when they are admitted. (C10)

Socio-cultural realm

Participants also identified complexity contributing factors in the patient's social and cultural realm. One senior physician described that:

> Quite a few of our patients are migrants. There the complexity can just be a matter of language, but also understandings of health and medicine, such as the role of a

> physician or a nurse. These can mean very different things for somebody from Cambodia, Uganda, or Serbia…. (I2)

In a similar vein, another senior physician said:

> Some African patients, for example, very much fear being stigmatized if they communicate that they are HIV infected…. [Or] they may go to their religious healer who says 'these drugs are bad for you' and things like that. So that is a different kind of complexity which one doesn't necessarily recognize at first. (I1)

Objectives & Behaviors

Treatment adherence and compliance

Among the subcategories of complexity moderators, patients' adherence to treatment emerged as a particularly salient factor curtailing providers' controllability. As one senior physician explains:

> The patient who comes early enough, has a preserved immune system, and no comorbidity but denies his disease and does not want to take drugs can be extremely complex to deal with. We have patients here who do not believe that they are HIV infected, or that HIV causes AIDS. These interactions can be very complicated…. [After some time] one just realizes that the patient didn't take the drugs.
>
> [In contrast], a patient who comes very late, say with a candida infection and other comorbidities, but is very willing to cooperate and to do tests, is very informed about the treatment, and tells the right things about the treatment, can be quite simple to manage because one can treat him. If the treatment doesn't work one has the right information. They are also very careful not to have drugs which could interact with their treatment so they will inform their GP and say: 'be careful, I cannot take this drug. The infectious disease physician said you have to be careful'. They come back with the list of symptoms they've had in the past three months, and a list with the drugs they did and did not take. That's a complex disease but easier to manage. (I1)

One junior physician described an example of a case in which the patient's non-adherence became a major complicating factor for care delivery:

> We have a patient who has had HIV for a long time and didn't take any medication. Then he developed a lymphoma. When this was discovered he agreed to start the HIV treatment. But during routine check-ups we saw that his viral load was rising…. He said he was taking his HIV medication but we didn't find any drug levels in his blood, so we assume that he wasn't taking the pills, at least not regularly. Now there's a risk of developing resistance to his HIV treatment, which would mean we would have to switch to another therapy which might interfere with the ideal treatment of the lymphoma. It would cause a vicious cycle and suboptimal care of the tumor.

Patient's health objectives

Participants also noted how understanding the patient's own health objectives was important for successfully managing complex cases:

> For patients, some things may be more important than [they are] for the physicians. For the physician, in general, the more acute a problem is, the more important it is. If a patient comes in with bacteraemia, bacteria grow in his blood and will kill him if we don't treat it correctly, this is the important problem for the treating physician…. But if [that] patient has hip pain every day for the past ten years and will maybe have it for the next ten years, he will have hip pain as well; this bacteraemia is only a very small episode in his life. So the focus is sometimes very different. This is important information that one can get from one's patient. (G1)

In a related vein, one senior physician explained how in designing treatment plans for complex cases they 'have to find solutions for multimorbid patients that are feasible at home, because they are not living in the hospital. We often forget that as physicians because we only see people as patients in a hospital'.

Knowledge and personal resources

Disease knowledge and literacy

Participants explained how a patient's own understanding of their disease, and the ability to communicate their knowledge with providers moderated how the latter perceived care complexity. A nurse gave the following example of a patient with a high degree of literacy and knowledge about his disease:

> I noticed he had a thorough understanding of his illness. He was interested in lab results, asked questions, was very perceptive of changes and communicated those to us. I had the impression that he could assess his situation very well on his own. It helped me to understand where we stood. He had had this carcinoma for a long time, and he knew how his body functioned, so I didn't have to start from scratch…. Patients who live with a chronic illness for a long time are very different to deal with than patients that don't know anything or have just heard their diagnosis. (C6)

In contrast, a junior physician noted that some patients are not receptive to information on a disease, but just want therapy:

> When one tells them, 'You have a chronic hepatitis B, you're sixteen years old, it's not

> a problem now but it could become a problem,' they are just like 'Why don't you just give me my medication?' (B7)

A senior physician noted how the availability of online resources has increased patients' disease knowledge and literacy, and how a patient's knowledge about the disease and treatment can influence the physician's controllability:

> [Patients with] chronic illnesses have had the opportunity to gather information about the disease for a long time. Often they know things even better than the physicians. I think that this is something that has changed with the availability of electronic information.… An informed patient is more likely to keep on going with the treatment when problems arise, [whereas with] patients that don't understand the disease or the treatment, there is often a time where they become fed up and say, 'I've had enough, I want to go home. Please stop….' Then one has to discuss and negotiate and so on. (G1)

Energy

Within the category of personal resources, participants discussed the degree to which patients had the energy to cope with their conditions as one of the most important moderators of perceived complexity. As one senior physician notes:

> Patients with multimorbidity always come to the point where they get tired, and they don't have the energy to take the next step. Then one has to try to motivate them. The psychological aspect of those treatments is important. (G1)

Yet one nurse explained:

> Being multimorbid doesn't have to mean being limited or very ill. One can be very vital and active. There are people who come here with multiple conditions, but they seem to lead their lives and somehow manage to find a balance. (C2)

Financial resources

In comparing her interactions with multimorbid and non-multimorbid patients, one junior physician explained the role of a patient's financial resources as follows:

> When I talk to [a multimorbid] patient, I have to go through more points and ask more things about his wellbeing…what kind of social insurance or money does he have? Can he cope financially?

Discussing an example, she notes:

> The goal was to have him stabilized on HIV medication so that his virus was suppressed, he wouldn't have any side effects and would feel well. And I wanted to

> treat his hepatitis C, but then the medical insurance said they wouldn't pay so there was nothing much we could do at that moment, and we said okay, let's put it on hold, we'll wait and maybe next year the limitations will change.

Complexity Moderators: Care Provider Level

Our findings show that providers' perceptions of care complexity were also moderated by their personal competencies and resources.

Experience and expertise

Participants repeatedly noted the critical role of experience as a key resource for dealing with complex cases. As one junior physician reflected:

> The capacity to synthetise what is important and what is not, is an experience thing. I think I am doing it much better than one year ago, and I will be even better a year from now. (B7)

One senior physician explained how the source of complexity changes over time, as one gains experience with complex patients:

> In the beginning one is more concerned with and focused on objective complexity, problems that the patient has. It's hard to know what to do first. Should I first treat the heart disease or the infection? One expects that if one has a plan and prescribes a treatment, the problem is solved. With time that kind of complexity gets more manageable. But [then] one recognises another type of complexity: the treatment strategy that fits patient one can be completely wrong for patient two even if they have the exact same disease. Because of the cultural environment, or because they have another understanding of the disease, or because one of them is depressed and I didn't recognize that. The interaction with the patient, the family, the culture…all these things become more important, and in the beginning, it's very hard to recognize and appreciate that. [Later, one develops] a broader view of a patient and also has these bad experiences, where one made these fantastic plans and the patient just didn't take his drugs, and one becomes incredibly disappointed. And one also develops a better understanding of what not to do in certain situations. [For example,] guidelines say one should screen for prostatic cancer every year, but with time one says, well this patient has other problems than screening for prostatic cancer. One has to fix other things first. And one also realises that one cannot treat patients if the psychosocial problems aren't dealt with. That's very hard to learn and difficult to train in others. (I1)

Another senior physician noted:

> The more experience I have, the more I see that simplified guidelines do not actually fit everybody. The more complex the case, the less they fit. We have to be aware of when simple guidelines don't fit the process of diagnosing and treating a patient…. One develops a feeling for when a case is more complex and needs more time for

interviewing, for thinking outside of the box. (I2)

Time

Participants noted that managing care for complex patients requires considerable more time resources than for less complex patients. As a senior physician commented:

> [There is a] mounting financial pressure on the health system…. [I'm concerned] that we will not be allowed to deliver the best care in complex cases because of financial restrictions. (I2)

Another senior physician discussed the repercussions of economising time on complex cases:

> If one doesn't invest the time to coordinate the whole process in the beginning, one will lose more time at the end of the day because one will have to do it later anyway. (G1)

Complexity Moderators: Care Context Level

Participants identified care coordination challenges in three domains: cross-disciplinary, cross-professional, and cross-level. Each of these coordination challenges influenced providers' perceived ability to control a patient's health state. Higher case complexity and higher perceived care complexity were associated with more intense coordination requirements.

Cross-disciplinary coordination

Cross-disciplinary coordination concerns the management of interdependencies across a patient's health care providers (e.g. specialists). As one senior physician noted:

> With multimorbidity there are a lot of different [specialists] involved. There is the infectious diseases specialist, the internal medicine specialist, maybe a psychiatrist, a rheumatologist…. One problem is that you have to make sure to obtain all the information from those involved. If anyone starts doing something…it will affect other problems as well. And often information gets lost because it takes time to inform each other, and not everybody does it. (G1)

Participants often described the need to organise care for complex patients across care providers, in the form of a 'care team'. As one senior researcher explains:

> If one only focuses on the treatment, but skip steps in building a care team and doesn't consult with other disciplines, it won't work. Interns and junior physicians are often not

> very happy when one organises grand rounds, and discusses the patient's problem for hours with other physicians, because it takes a lot of time. But I try to explain to them that they really have to take this time, or the treatment will not be successful. (G1)

Cross-professional coordination

Cross-professional coordination entails managing interdependencies among practitioners in the patient's broader care environment. One senior physician explained these kinds of interdependencies with non-medical professionals as follows:

> Many of our patients are in difficult social situations. It is not only communicating with other physicians but also communicating with social workers and health insurance and so on. That's an important part of the work, especially for patients who are migrants or drug users…. For example, it's more difficult to have polymorbid issues dealt with when someone comes in with a translator. Prisoners come in with the police, so one has to coordinate their consultations…. These issues take a lot of our physicians' time on a daily basis. (G3)

While the need for cross-professional coordination often increases complexity, participants also noted ways in which coordination across professions helped to reduce perceived care complexity. As one junior physician explains:

> Social workers provide incredible benefits. [They save] a huge amount of work. Having to fill out forms that we are not familiar with and writing letters we don't usually write [and] don't know the official formulations for, would take us double the time. (B 6)

Cross-level coordination

Some participants also identified differences in tenure and hierarchical position as a factor influencing their ability to coordinate care for complex patients. One junior physician described how she initially had difficulties soliciting help from specialists outside the department:

> In the beginning, I was not very confident calling other specialists. When they said they couldn't come I'd say 'ok, no problem'. That was not helpful. I learned that I had to be stricter, and approach it with more power and confidence, and more clarity about what the patient needed…. Sometimes, when we leave the choice to the specialists, they'll say no. But if we say, 'You don't have a choice, you have to see this patient. It's an emergency', it works better. (B1)

DISCUSSION

Since the early 1990s, global healthcare systems have come under economic pressure in the face of increased health care spending.[22] As a result, there is an increasing demand on health care providers to effectively treat, document, and economize on the time spent on complex patients with high care requirements. However, what constitutes a complex patient remains poorly defined. This study sought to inform medical education in domains characterized by high patient complexity (e.g., general internal medicine and geriatrics) by identifying the scope and impact of patient complexity contributing factors and the role of practitioner experience in complexity perceptions. In so doing, our study advances the much-needed expansion of the concept "complex patient"—moving from objective complexity-contributing factors relating to the patient's medical health state to a broader, holistic notion, including non-medical factors. Our findings have important implications for medical education and the literature on patient complexity.

First, the study provides insights into complexity drivers in clinical practice. Whereas previous studies have provided important insights into general factors contributing to health care providers' perceptions of patient complexity[1,2,11], our study and conceptualization extends prior work by addressing patient complexity from the health care provider's perspective as a combination of patient characteristics and practitioner experience. As Doessing and Burau conclude in their review of the literature on multimorbidity, prior studies on care coordination for complex patients have offered little insights into differences between care providers.[14] Our findings show that the extent to which complexity contributing factors influence providers' perceived controllability is to an important degree determined by

experience. Table 1 (cf. Appendix 1) summarises the perceived controllability of complexity-contributing factors according to the provider's level of experience.

The findings in Table 1 show that understanding the role of practitioner experience in the perception of and approach to patient complexity has important implications for the development of curricula at the undergraduate and post-graduate levels, in particular in medical fields such as geriatrics and general internal medicine, in which skills for managing care for older multimorbid patients are necessary. For example, the findings highlight that more experienced medical practitioners report high perceived controllability over complexity moderators at the care provider level and care context level, whereas these factors constitute an important driver of perceived patient complexity in less experienced practitioners (i.e., low perceived controllability). More specifically, the findings suggest that in designing training programs in areas where patient complexity is high, medical educators should place particular emphasis on on developing skills to recognize 'weak signals' of patient complexity, managing non-standard/non-guidline cases, resolving cross-professional information asymmetries, and coordinating care across levels of seniority.

While our study is rooted in HIV clinical practice, the complexity contributing factors identified in this study may translate to the treatment of other chronic illnesses. In HIV clinical practice, improvements in antiretroviral therapies have tremendously increased the life expectancy of patients. Medical practitioners in our study explained that as HIV patients age, multimorbidity poses new challenges for managing patient complexity. While the medical aspects of complexity arising from comorbidities emerged as potential drivers of perceived complexity, providers' subjective experience of complexity was greatly influenced by more general, non-medical factors such as patients' adherence to treatment and the

organisation of the care context. Our findings thus reinforce and add detail to studies that conceptualise patient complexity from the health care provider's perspective as a function of the patients' physical and mental medical conditions, socioeconomic factors, and behaviours.[1] Nevertheless, stark differences in the clinical practise of different medical specialisations mean that improving patient outcomes requires discipline-specific insights into care complexity perceptions.

Our findings also elaborate prior work by not only identifying complexity-contributing factors but also explaining the relations among three dimensions of complexity. Importantly, we introduce the concept of complexity-moderating factors to provide a basis for identifying the conditions that determine the extent to which case complexity translates into perceived care complexity. In line with previous studies, health care providers in this study explained that case complexity drivers (i.e., multimorbidity and interdependencies among physical and mental health state factors) generally increase the potential for perceived complexity. Yet, our study participants also argued that complexity is only perceived as such to the extent that other patient characteristics ("case complexity moderators") and aspects of the care coordination context ("care complexity moderators") enable or constrain the controllability of the patient's health.

By conceptualising the relations among case complexity drivers, complexity moderators, and perceived care complexity, our study contributes to the design of more effective interventions and care delivery models in high-complexity health care settings. Medical professions are becoming increasingly specialised, while the proportion of older, more complex patients rapidly increases. Given these developments, it is critical that we understand the sources of patient complexity from the health providers' perspective before designing

technological and organisational solutions that help professionals manage the cross-disciplinary and cross-professional coordination of complex cases.[23]

Third, our findings and framework offer important practical insights for health care training and -education. As corroborated by several of our participants, there exists a need for aligning medical education with the clinical reality of managing care for complex patients. The framework developed in this study may serve as a starting point for identifying the interpersonal and coordination skills and competencies required from clinicians who provide care to complex patients in highly complex settings such as general interal medicine and geriatrics. Fourth, to advance the clinical application of our findings, we present ten questions (Table 2, Cf. Appendix 1) that may assist health care professionals in unravelling and communicating the nature of patient complexity. By making patient complexity more explicit, these questions can help health care students to more effectively identify its drivers, and develop the essential skills to manage complex patient care in daily practice.

Limitations

The results of this study have to be interpreted relative to its empirical and methodological limitations. First, our interviews focused on the complexity perceptions of practitioners working in a single setting—a university hospital's department for infectious diseases. While the physicians in our study also perform consultations for the hospital's inpatients, our interviews emphasized complexity in the ID department's treatment of outpatients. Second, the framework is grounded on data from a Swiss hospital, and should not be generalized to settings where resource restrictions are even more severe, and access to help from other specialists (e.g., social workers) is more limited. Third, our study includes both nurses and physicians informants. It should be noted that while the physicians included in our study work

exclusively for the ID department, most of the nurses working in the ID department also work for an internal medicine outpatient clinic. Moreover, in the outpatient clinic that we studied, junior physicians have the primary responsibility over coordinating patient care. It is likely that these setting-specific characteristics influenced our findings. To validate our framework, further research needs to investigate other inpatient and outpatient settings.

Conclusion

Studying health care providers in HIV clinical practice, we developed a framework explaining how a patient's case complexity translates into a care provider's perceived care complexity. Our findings show that case complexity is moderated by the provider's sense of controllability of the patient's health state, and complexity moderators, including non-medical patient characteristics and the coordination context in which care is delivered. The framework may be used in training and educating health care providers with complex patient care responsibilities, and for designing future care models and interventions. Follow-up studies are needed to validate our framework in different settings, and to illuminate specific strategies and resources that providers in different professional roles utilize in order to manage perceived complexity.

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APPENDIX 1 : TABLES

Table 1. Perceived controllability of complexity-contributing factors according to provider experience

Complexity contributing factors	Provider Experience	
	Low	High
Case complexity drivers		
Multimorbidity & polypharmacy	low/medium	medium/high
Changing health state	low	low
Mental health	low	medium (in collaboration)
Patient level complexity moderators		
Age	low	low
Managing patient's extended care network (e.g. family)	low	medium
Cultural and language differences	low/medium	low/medium
Non-adherence to treatment	low	low/medium
Diverging patient-provider health objectives	low	low/medium
Disease knowledge and literacy	low/medium	low/medium
Energy	medium	medium
Financial resources	low/medium	low/medium
Care provider level moderators		
Recognizing 'weak signals' of complexity	low	high
Managing non-standard/non-guideline cases	low	high
Allotting time to complex patients	low/medium	low/medium
Care context level moderators		
Cross-disciplinary coordination	medium	high
Resolving cross-professional (e.g. nurse-doctor) information asymmetries	low/medium	high
Cross-level coordination	low	high

Table 2. Complexity checklist

Case Complexity (patient state)	Care Complexity (coordinating and providing care)
1. ***Medical health state:*** What are the patient's physical and mental comorbidities, and how may they interact in treatment? 2. ***Demographics:*** How do age, socio-cultural, and economic characteristics of the patient impact diagnosis and treatment? 3. ***Adherence and compliance:*** What are the patient's health objectives and barriers to adherence and compliance? 4. ***Personal resources:*** What is the patient's level of understanding, energy, and capacity for coping with disease, treatment, and changes?	5. ***Care team:*** Who are the different care actors and what are their roles and interdependencies? Are treatment roles and objectives well-defined, aligned, and shared? 6. ***Complexity perceptions:*** What is complex for whom? 7. ***Coordination barriers:*** What are the potential barriers to cross-disciplinary, cross-professional, and cross-level coordination? 8. ***Coordination tools:*** Which coordination and communication tools are feasible and appropriate?
9. ***Controllability:*** What sources of complexity can/should I control, coordinate, delegate, or defer? 10. ***Change:*** How may the sources of complexity develop in the future?	

Part III Appendix A

Interview Quotes from Essay II

Appendix A 1 : Examples of Uncertainty Moderators Quotes

Uncertainty Factors	**Examples**
Space Clusters	*Near the cardiology departments, we try to have anesthesiologists so that we can collaborate with them more easily. So we just have to pass by as their department is close to ours, and they do not need to walk for long distances in order to ask something* (D1*)
Retrospective-Reconstructed Future	*The challenge is to find solutions not only for now but also for the long term and to put them all in one comprehensive package. First, we want to understand how they are organized in collaboration with other clinics. Second, we develop a concrete solution, like if we really come to the conclusion how would we use additional technologies and resources and integrate them into the existing process. Third, if we really put it into place this additional resource (into the treatment process), let us look into the future: how long will the solution last? So, the process for now is short-term solution, long-term perspective.* (C2*)
Prospective Abstraction	*In collaboration with different specializations, there are pre-set standards for treatments by specializations for certain problems They are used by everybody. These are often very useful and available for everybody. Often doctors from specialized institution are a part of developing these standards for future use. So we use this obviously. At some time, you have specific problems that are only done in a certain thing, and then you develop your own standards. But pre-set general standards are needed in the beginning* **(**C1*)
Similar starting points – Different patient trajectories pathways	*There is a general process that patient run through. But for a specific disease, one step in this process is more important than others. There are some general steps that every patient will undergo and there is some specific needs that some patients have. This requires additional that is generally managed by a clinician who is responsible for the patient, and this person decides what is important which steps will be taken. So the care pathway ends in a different place despite the same general processes* (D 2)

Appendix B : Quotes from non-clinical actors (examples)

Second Order Dimensions	First Order Categories with examples
I) COORDINATION COMPLEXITY: Predefined Parameters	*Specific Roles-Specialized Documentation Production* "Consilium patients are patients who are in the house and have no cases with us. We don't write reports that we have to send, we simply put history entries in IPDOS, it's a relatively small paper. And then there are the ambulatory reports, where the problem list needs to be corrected and the laboratory results have to be printed out. We have it to give it to the doctor, who then gives it to the senior physician and then back to us to send it." (E 3) *Approximate, Domain-relevant specific knowledge* "What is certainly important is the medical terminology. It's an advantage to have some little knowledge of anatomy. That you know what is from where" (E1) *Locations/Orientation through patients* "When we try to locate and structure our trial there may be problems. For example when a patient does not show up for an appointment. And then, the sponsor says ''there are protocol departures." You just can't influence that as a study nurse: if the patient doesn't come, then I can do nothing about it. Then I can certainly be more empathetic" (D 7) *Intuitive Feel of ''what feels with what"* In the meantime, everyone knows which case is coming where and for whom. For example when it comes to vaccinations, we connect it here to the doctor of the ambulatory service. (E 3) *Merging of activities between specialisations and/or roles:* I actually work as a monitoring, clinical research (assistant). It's a bit of a mixed function and that changes depending on which e-mail I have to read and which phone call comes, who is in my office. That is fluid, the functions merge into each other. *(D7)* *Merging of internal digital networks*

Form vs. Content Dichotomy	‘’Yes, IPDOS is where we merge reports and we can look up foreign clinics through it. The Polypoint RAP and the SAP, those are more programs where we can just look up something selectively. So mainly SAP. And the Windscribe, the most important one that cab be linked and merged to SAP and RAP’’ (E 4) *Turnover of Assistant Doctors* “There are always doctor changes. They are usually there for a couple of months and then when they write a report, they have no idea at all. Although they get it all, already by computer, they get templates, but nobody cares about it. “(E 3) *Anonymised Patient Information Transfer* The outpatient reports from the polyclinic and the patient information they're also in IPDOS, you can see and transfer them, but they're still being printed out. So we'll put them in one file with infectiology results only. We're still archiving them, for the time being. For how long? I don't know. (E2) *Tracking Patients-Doctors interactions* ‘’And when it comes to a patient, there is consultation service and then we see which doctor has seen him, who is taking him now or who is on duty now.” (E 3)
II) WORKFLOW COMPLEXITY: Activation through Segmentation	*Digital form of activation and task assignment*: “For the consultation service, we have the triage services that work with the beeper. That is, the doctors call and then we look, which doctor is on duty, if it is a first consultation for a patient or if the patient has re-entered after a certain distance, then it is a first consultation, as we say to that. And then we call the doctor and connect him. “ (E 4) *Automated Doctor-Patient Assignment* “Two years ago, we began to use the viewfinder where we first pick up the and then look to which doctor and to which patient it is forwarded. +(E3)

Perpetual Storage and Recreation of Information	*Specific Channels: Specific tools, specific use, specific storage*: "On an excel list I put the electronic patient employee data entries. I have to make this list in such a way that only myself and my colleagues can access it. And I have to send this roster to all the doctors to check. So I need a vessel where I can collect all the information and then transfer it. And from this transfer it goes to the third system, where the patients can be planned. "(H 1) *Physical vs. non physical outputs*: "Entry reports are only created for the HIV patients because they will come for years. So when they are new, the doctor dictates a problem list, as well as an entry report, we then write it. Problem list is then stored in IPDOS for each case. It is only later that the family doctor reports comes in: the doctor also dictates and we write it. And then when we write the report to the family doctor, the problem list is also corrected and printed out and sent with it." (E 3) *Duplication Processes*: "For registering information we have to duplicate and do anything three times" (H 2) *Translation into physical forms Timing and Collaboration of Document Use*: Doctors write a course of events in IPEDOS while we write a consilium report that is already in IPEDOS as well. We just have to wait until the doctor is finished. And unlike with printed documents, the doctors may have to go somewhere else quickly and leave it open. And, we'll have to wait until he logs out again (E 1) *Recycling of relationship networks*: I have experienced many situations where I now know how to react. If the medication doesn't come, I know exactly who I can turn to. You're just so networked and you know that for any new situation, I'll contact you (D 5)

Appendix C : Quotes from clinical/healthcare provider actors (examples)

Second Order Dimensions	**First Order Categories with examples**
I) PATIENT COMPLEXITY: Complexity Readiness (Senior Doctors)	*Constructing Common Frameworks* "When you are looking for a common solution, you have to keep in mind that the patients had the opportunity to gather information about their (chronic) illness or the disease for a long time. They know often know their conditions even better doctors in special situations. Patients often want to be involved in the process of choosing the correct treatment. Or they want at least to hear the different options." (G 1) *Common Anchor Points* "The aim is that the patient will tell us about the negative and the positive aspects of doing some things. So we try to have him relate to the positive things that would come out of his actions. You can use the scale technique: "on the scale from one or from zero to ten, how motivated are you to take your drugs?" And he is not going to tell you zero, he is going to say five for instance. And then we can make him explain why it is five and not zero and build on that. "(G 3) *Past Historicity (from abstract to concrete)* "The first thing is to ask the patient whether what is his history of medical illnesses. And then the next step of course, is the physical examination where I'll find more clues for multiple illnesses. Then the next thing will be the laboratory exam and you'll find more precise indicators of multimorbidity (for instance dyslipidemia)." (G 4)
Adjusting Patients' values to goal oriented systems (Nurses)	*Simplification and Reduction of Perceptions:* "Whether a patient is complex simply depends on the (practical) specific situation. For instance, a patient says that he had an allergy on the last infusion or drug last time. And one has to take specific action on that for instance, giving another drug or sending him to an allergy specialist. "(C 3)

Evidence-based misalignment perceptions (Assistant Doctors)	*Expanding Domains of Perception*: "The patient is not complex even though he has many illnesses because he can perform his daily activities independently. Complexity occurs when something new adds to it. For instance, the patient has difficulties climbing the stairs. And something changes not only in his daily life but also in his experience. And it can be something very small that nevertheless, bothers him a lot. Or it can be something important that requires further research and exploration from my side "(C6) *Outside hospital criteria*: "In contrast to the hospital, many elderly are alone at home, do not eat correctly and do not take medicaments regularly. This, plus social isolation degrades their state dramatically. But when they come to us, they eat correctly, they are regularly cared for and they take medications. So they can recover rather quickly. But once they are home again, the same problems arise" (C 10) *Signal Coding and Decoding* "Either he will tell me directly or by asking questions, I try and find something. I kind of scan different topics, and then maybe he won't tell me directly that there was a problem there but maybe I can kind of feel it by what he is signalising indirectly" (B 5)
II) CARE DELIVERY COMPLEXITY Empirical ad-hoc approach (Senior doctors)	*Streamlining Processes*: "Very often, we choose very broad approaches which are not in fact hypothesis driven. So the more complex the possibility of reasons for a disease is, then the more broader tests I will order. For instance, I will not only test for the most important pathogens, I will ask for the five other categories of pathogens when they obtain a sample form the lung. So the more complex the patient is from the beginning, usually the more complex the plan is that we present with broader diagnostic approaches. "G 4

	Conditions Mutability: "An important point is that some patients have very rapidly changing kidney functions. This is important because most medications are secreted by the kidneys. And if you don't take care about your kidney functions, you may overdose or underdose your treatment. So I always want to see how the kidney functions are. And then we do the fine-tuning of our antibiotics by kidney function." G 1 *Expanding through patients' modification* "What was difficult is that the pneumologist and the ID physicians did always had the same opinion about what to do next. And it's always also shifting where the priorities are, at the very beginning when the patient could not breathe any more, it was not me that had the lead, it was the ICU guy that had to work with the respiratory machine. So it's always a little bit changing who is leading the team according to how the patient's state changes...It happens in the function of what the team thinks is the next most big problem. " *(G1*?)*
Dialling Specificity (Nurses)	*Level of details and granularity*: "There was a lot of question marks when he came for therapy: we did not know if his carcinoma increased, whether there was additional illnesses or whether his situation at home changed. But I noticed that he had a high understanding of his conditions. It was vey useful to have such a specialised information at this level. But in other situations, patients do not precise ideas about their conditions and their treatment and I must act accordingly. "(C 6) *Cyclical vs. Reactive Role Change:* "Initially, my task was to accompany this patient for the injection. And then we talked he told me that he fainted and that he pain sometimes, that quickly dissipates. I had to react of course. I looked at it with the doctor, and then my role changed. I had to make an EKG, to take blood and to reassure the patient" C3

Compensation Effects post hoc (Assistant Doctors)	*Stable Starting Points-Unpredictable Developments* In the beginning when he came, we had everything in control. His life was under control, he had a 100 % job, family, a daughter, everything was going fine. I thought it was pretty easy to manage his case. Looking back I think maybe I didn't react soon enough with his hypertension when that problem arose. We tried treating it but it didn't react to the medications maybe quickly enough. So maybe I wasn't aware of these problems that could arise. So when he comes I plan more time with him so that we can we can deal with all these factors *(B 5)* Age Configurations (Expected Patterns) Complexity depends on the age of the patient. Young patients with HIV are not complicated. And then older patients with HIV, like 60 years old, they begin to develop sometimes some kind of renal failure because of the therapy. And we have to switch the therapy (B 7)