From Resilience to the Design of Antifragility

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***Abstract*— Resilience has been highlighted for the last few years as one of the most important mechanisms of survival and evolution of systems. However, with the complexity and exponential advance of Information and Communication Technologies (ICT), volatility, uncertainty and disorder have become constant in our daily lives, creating the need for adjustments and improvements in resilience, in order to maintain its efficiency. As a consequence, various skills, such as adaptation, learning, self-organization and others, have been added to it, increasing it to antifragility. Focusing on this process of evolution, this work confronts the dissociation between resilience and antifragility, proving in the end, that antifragility is the resilience in its most advanced form.**

Keywords - Resilience; Antifragility; Complexity; Information and Communication Technologies; Stigmergy.

I. Introduction

Today, with days full of change and uncertainty, shocks and unexpected events have become more frequent, making it difficult to maintain a constant equilibrium and stimulating the emersion of a new mechanism of resilience [1][2], no longer centered on the search for balance nor on the return to its original form, but rather on the development of competences which promote improvements to the systems, allowing them to evolve through stress and disorder.

In this scenario, with increasing complexity and widespread diffusion of Information and Communication Technologies (ICT), learning and self-organization skills present in complex systems become essential to survive, providing to the systems a greater adaptability and efficiency, which allow them not only to resist, but also to evolve in the face of chaos [3].

This "new" mechanism of survival and evolution, called resilience by many, is called antifragility by Taleb [4], describing it as something beyond resilience because it improves with shocks and it is not only resistant to them. However, such dissociation between resilience and antifragility does not seem coherent to us. Our objective in this work is to demonstrate that antifragility and resilience should not be dissociated since antifragility corresponds to an advanced and improved form of resilience.

The rest of the paper is structured as follows. In Section II, we present a bibliographical review addressing (1) resilience, through its epistemological origin and the definitions of Holling [5][6] and (2) complexity and ICT, and how they are intertwined with resilience. In Section III, we show the antifragility and the evolution of resilience and we compare their definitions in order to prove their similarities. Finally, in Section IV, we present our concluding remarks.

II. Resilience

A. Its Epistemological Origin and The Holling' Definitions

Coming from the Latin term "*resiliens*", whose meaning is "to turn back", resilience, in general, refers to the ability of an object (agent or system) to return to or recover its original shape or position after having been stressed [7].

Initially addressed in studies with children, in which it was linked to the degree of adaptation of beings in different situations [8], resilience was defined as: "*the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables*" (Holling [5]). However, after other studies, it was evident that resilience is not only related to internal factors (or characteristics of being), but also to external factors [9] - [13].

Still in this light, Rutter [14] states that resilience does not come from the personality of each subject, but from a dynamic process that varies according to each context and which presents itself in different ways, once each person assimilates each problem in a unique way [15].

Moreover, just as we are influenced by the environment and other agents, we also influence them, establishing an interdependence between systems, agents and environment, from which unpredictable scenarios do emerge, permeated with uncertainties, volatility and instability, in which only dynamic mechanisms will be useful in the search for survival [16]-[20]. This idea is similar to Jen's idea [21], where new non-qualitative features emerge in a structural stability through of certain dynamic characteristics of the system, and the idea of De Florio [22], where resilience is not a property that systems have or do not have, but rather the emerging result of a dynamic process.

In this context, we came to see resilience in a more holistic and systemic way, shown by Holling [6], with the improvement of its previous definition, through the categorization of resilience in:

1) *Engineering Resilience*: initially described as the ability not to suffer from disorder, remaining in constant equilibrium [23], the resilience involved here acquires a more dynamic character, which allows the system to change or move in the face of stress, but, at the end of the process, there is always a return to the initial state or position. To this, in its more static version - where the balance is preserved and always maintained in the same form - the definition of robustness was linked, where robust is the one that remains intact, resistant to shocks and disorder [4];

2) *Ecological Resilience*: linked to the idea of dynamic balance, in which systems change and evolve when they are disturbed [4][6], changing state and/or position after stress, in this strand, adaptation and self-organization mechanisms are responsible for allowing systems to learn and improve with respect to past situations, in order to better take advantage in future ones [24][25].

In line with this broader form, and in view of the interconnections between environment, systems and their emerging properties, a more comprehensive and anti-reductionist approach encompassing complex elements present in our daily lives becomes necessary [4].

B. Its Relationship With The Complexity & ICT

Broader than the traditional thinking, complex thinking chooses to adopt the duality, recursion and systemicity, with the aim of highlighting and covering all relationships and influences among environment, systems and agents, as well as their results and forms of dissemination [26][27].

Together with complex thinking comes the General Systems Theory (GST), which argues that every system around us is complex, open, dynamic and adaptive. Thus, through the interaction between its parts and with the environment, new properties emerge and allow the survival, adaptation and evolution of the system, through mechanisms of evolutionary selection [16] [28].

In general, Complex Adaptive Systems (CAS) are formed by a set of diverse agents that get directly interconnected and act guided by common goals and by the spirit of cooperation, which allows them to develop collective competencies and evolve as a whole [29]-[32].

Still under the logic of complexity, equilibrium and stability are rejected because they do not provide the system with any learning or stimulus for its improvement. In contrast, the state "on the edge of chaos" and a no-interference policy with bottom-up structure are exalted as enhancers of the growth capacity and evolution of the systems [33]-[37].

In this context, stigmergy begins to gain prominence. Described by Grassé [38] as a coordination mechanism used by insects - where an insect leaves traces in the environment that influence the later work of the same or others, without any form of planning, control or direct interaction between the agents [39]. Nowadays, we can see stigmergy in most of the complex systems that surround us [40]. Encompassing mechanisms of self-organization and learning, in addition to elements of cognition and cooperation, stigmergy provides to the systems the ability to adapt and evolve [41] [42].

In addition, it is important to note that every complex system consists of networks of interactions between its parts, and it is important to consider its modulation and technologies, as these aspects directly interfere in the capacity of resilience and system evolution [43].

Structured systems under dense networks - with high degree of interconnection - at the same can be very efficient - with large and rapid exchange of information [44] - or very problematic, since the high proliferation power of this type of structure can quickly lead the system to collapse [45]. On the other hand, systems based on more specialized networks, with low redundancy (number of agents performing the same function) - tend to be less resilient, suffering more with the removal or inactivity of one of its agents, especially if they are the most interconnected (hubs) [46][47].

In this context, ICT also gain prominence, since they allow systems and agents to interconnect in different ways, which stimulate the emergence of new contexts, paradigms and cultures [48]-[50].

Such as a complex adaptive system, ICT, when integrated into the routine of agents, become powerful mechanisms of relationship and of dissemination of knowledge. They aid agents and systems in their processes of innovation and learning [51], either through smoother routines or through routines that drive systems "on the edge of chaos" [52].

III. The Antifragility and The Evolution of Resilience

As an intrinsic property of complex systems, resilience makes the system able to assimilate and adapt to its surroundings, allowing it to evolve in the face of disorder rather than stagnate or succumb [53]-[56].

As Hayek's neoliberal discourse dictates, no agent should interfere with the natural trajectory of the system and/or prevent its mechanism of self-organization from acting, as this may weaken the system or even lead to its extinction [4]. In addition, we should not try to predict the future based on past data – because in the face of constant changes the future would appear unpredictable – but rather accept its uncertainty and constantly seek to improve our adaptability to cope well with what will come [57].

This results in a "General Resilience" that gives systems the ability to deal with uncertainties, changes and surprises through mechanisms of adaptation, learning and self-

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organization, enabling systems to improve when faced with shocks and disturbances [58].

In consonance, we see the Adaptive Cycle of Resilience (ACoR), which emphasizes that every system, at some point, will go through ruptures because even in equilibrium it accumulates fragilities and vulnerabilities [52].

Therefore, it is essential that systems improve their resilience mechanisms, but not only that. The antifragility emerges here, since the systems should not only seek to resist, but rather seek to improve when exposed to volatility and disorder [4] [52].

As Dahlberg [3] does for resilience, Taleb [4] also portrays the malfunctions of intervention for antifragility, arguing that both the optimization and the specialization, from human intervention, make systems more vulnerable. In addition to that, antifragility also acts as a powerful mechanism of risk mitigation [59] when using creation processes and recombination of elements to face the unpredictable [60].

Aven [61] also highlights that, in practical terms, when explaining a situation, we can easily replace the concept of fragility with that of resilience – fragile is the one not being resilient - which again demonstrates the incoherence in the distinction between antifragility and resilience.

In the field of industry, De Florio [62] shows the antifragility as an advanced mechanism of resilience, which is distinguished by its elasticity and machine learning ability. An idea also defended by Hole [63], which explains fragility, robustness and antifragility as stages of a spectrum, in which antifragility figures as an advanced degree of resilience.

Finally, in Table I, we interconnect concepts and definitions of resilience, robustness and antifragility, in order to demonstrate their similarities and resemblances, proving that antifragility is a type of resilience, in the broadest and most advanced form, in a quantitative way.

TABLE I - COMPARING DEFINITIONS OF RESILIENCE, ROBUSTNESS AND ANTIFRAGILITY

Resilience	Robustness	Antifragility
Characterized by low vulnerability to perturbations. Is the "*ability of these systems to absorb changes of state variables, driving variables, and parameters, and persist*" [5]	Robustness is a property of simple or complicated system characterized by predictable bahavior, enabling the system to bounce back to its normal state following a perturbation [3]	
Positive end of the distribution of developmental out comes among individuals at high risk [64]		It not only survive disturbance and disorder but actually develop under pressure [4]
Dynamic process encompassing positive adaptation within the context of significant adversity [65]		"*gets better with every shock*" [52]
An emergence property related to the self-organized behavior of SAC [30]		It not only resists the ravages of time but become ables to cope with an unpredictable future, through the creation and recombination of novel components [60]
"*Resilience requires a constant sense of unease that prevents complacency.*" [53]		"*The robust or resilient is neither harmed nor helped by volatility and disorder, while the antifragile benefits from them.*" [4]
It is the capacity to provide sufficient response to uncertainty together with a process of learning from doing and building a knowledge repository from tough experiences [66]		"*systems able to learn while enacting elastic and resilient strategies*" [62]
Resilience enables the system to cushion the effects of unforessen disturbances by absorbing the shock and adapting to changing conditions forward to a more advanced level better suited for future hazards [56]		"*being antifragile means being able to grow despite the crises that might arise*" [52]
Mashup of adaptative and absorptive capacity, fostered by innovation and learning capabilities [31,30]		Stronger through learn fostered by resilient strategies [62]
"*the joint ability of a system to resist (prevent and withstand) any possible hazards, absorb the initial damage, and recover to normal operation*" [67]		"*is a new way of thinking about mitigation risk*" [59]
Capability of organizations related to ordinary adoptive practices that lead the system to higher levels of efficiency [68]		"*is rewarded with good results and protected from adverse events*" [61]

IV. CONCLUDING REMARKS

At the end of this study, it is shown the equivocation when dissociating resilience from antifragility. This is because, after exposing some of the current definitions of resilience and confronting with the definitions of antifragility, we can affirm that antifragility is synonymous of resilience in its most advanced form *(Resilience$_{new}$)*, where systems, in addition to resisting stress and volatility, also grow with them, thanks to their adaptive capabilities.

As proof of this, we can return to the idea of De Florio [62] (1):

Antifragility = Elasticity + Resilience + Machine Learning (1)

where elasticity is directly associated with the idea of adaptability and machine learning with the capacity for self-organization and learning of systems. The main elements of stigmergy are as described in (2).

Stigmergy = self-organization + learning + adaptability (2)

Aligned with this idea, we also see the description of resilience given by Folke [24]: *"is not only about being persistent or robust to disturbance. It is also about the opportunities that disturbance opens up in terms of recombination of evolved structures and processes, renewal of the system and emergence of new trajectories "*.

Thus, in front of the necessities, the resilience has been improving until the "new" resilience, resulting from the mix of stigmergy and resilience (Figure 1) - in its simple form.

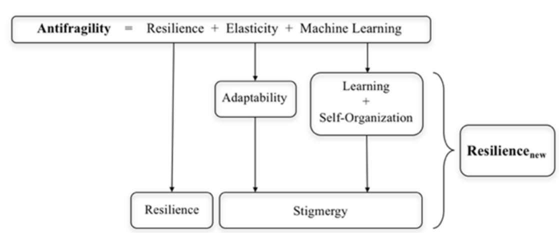

Figure 1. The Evolution of Resilience

From this, we can describe antifragility as (3):

$$\textbf{\textit{Antifragility = Resilience}}_{new} \quad (3)$$

In addition, Taleb [4], in portraying resilience through the figure of Phoênix – bird, which never gets extinguished, always being reborn from the ashes after its death - demonstrates its most archaic definition, which is today the synonymous of robustness, in which there is only resistance to shock, without any improvement nor learning. With such a description, the author is denying the evolution of resilience and refuting all its improvements, due to the increase in complexity and the widespread dissemination of ICT.

Thus, at the end of this work and after a vast review of the studies cited here, it is noticed that the increase in complexity and the introduction of ICT in our daily life triggered the process of evolution of resilience, which in its most advanced stage appears as antifragility.

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