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ARTICLE

Personality and Society in the Theory of Self-Organized Criticality

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ABSTRACT
Emerged in the domain of natural science, the theory of self-organized criticality (SOC) has spread to various fields over the past decades, achieving the status of an interdisciplinary paradigm. This article aims to answer three questions: Is SOC really a ubiquitous property of social reality? Does the SOC theory really substantiate the fundamental unpredictability and inevitability of social catastrophes? What contribution can the SOC theory make to clarifying the fundamental mystery of the relationship between human will and historical necessity? I performed a meta-analysis of the latest literature and summarized the results of my own case studies. So far, there is not enough empirical data to confirm that SOC is ubiquitous, although it has been proven that SOC is characteristic of many social systems—especially those in a borderline, transitional state. The SOC theory supports the idea that in some social systems for a fairly long time (even by historical standards), human will, act, and opinion can have a fundamental impact on the development of the whole of a system.

KEYWORDS
punctuated equilibrium, self-organized criticality, pink noise, history, society, politics, social transformations

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Object, Aim, and Questions

The theory of self-organized criticality (SOC) was developed in the late 1980s (Bak et al., 1988) in the domain of the natural sciences and almost immediately demonstrated its expansionist character. It originally emerged as an emphatically interdisciplinary concept, but soon it became a new scientific paradigm addressing a wide range of the most difficult, promising, and, in a sense, trendy research problems in various disciplines. Such claims are justified by the fact that the SOC theory has offered an explanation for punctuated equilibrium, a phenomenon that is very widespread in nature and society and determines the most intriguing and paradoxical properties and events (Podlazov, 2001; Zhukov, 2022).

This study considers the heuristic capabilities of the SOC theory in the social sciences and humanities (economic applications were not touched upon due to some peculiarities of SOC theory regarding economics). First of all, I sought to understand the contribution of the SOC theory to the development of ideas about the place and role of a person and a human act in society and history, especially in times of social cataclysms. Over the past two decades, a number of works have accumulated in which the SOC theory has been successfully applied to solve research problems in the social sciences and humanities. These are the publications that formed an empirical foundation for my meta-analysis.

My aim in this article is to propose answers to three questions:

1. Is SOC really a ubiquitous property of social reality as some promoters of the SOC theory have claimed, or are these claims overly optimistic due to the theory's rapid expansion?

2. Does the SOC theory really substantiate the fundamental unpredictability and inevitability of social catastrophes?

3. What contribution can the SOC theory make to clarifying the fundamental problem of the relationships between chance and regularity and between human will and historical necessity?

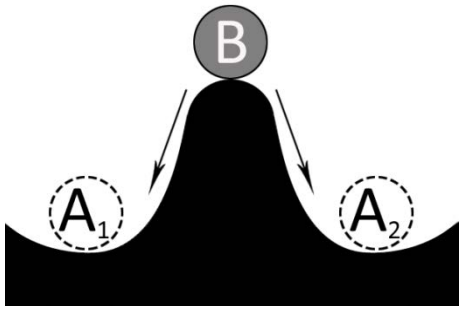
However, before proceeding with these questions, I explain what SOC is and review the literature on which my judgments are based.

What is SOC?

In a state of criticality, causal chains, even if they are triggered by weak local events, do not fade out too quickly and, in the end, can spread across the entire system. Self-organized critical systems can, over a relatively long time, self-adjust, or self-organize into a critical state. The assertion that such systems are, firstly, possible and, secondly, abundant in physical and social reality is perhaps the most surprising point of the SOC theory. After all, criticality is like a bifurcation point extended in time, a classic illustration of which is shown in Figure 1.

As long as the stone is on top of the hill, the choice of its trajectory can be determined by minute (even random) events. Thus, a nonlinear effect arises: the usual proportionality of causes and effects is disturbed. However, if the stone is already rolling down the slope after the bifurcation point has been passed, it takes significant effort to change its trajectory.

Figure 1
A Stone on Top of a Hill Is an Example of a System at a Bifurcation Point (B), Where/When There Is a Choice Between Patterns Leading to Different Final States (Attractors A_1 and A_2)



Note. Drawing by the author.

For a long time, it was believed as a matter of course that a system passes bifurcation points rather quickly. After all, if a weak, random impulse can push a system out of the bifurcation point, then it will not take long for such an impulse to appear. Real systems are constantly affected by a huge number of minor random events generated by internal and external circumstances.

Criticality, once again, is like a bifurcation point extended in time; as long as a system is in a state of criticality, it may at any moment break loose, transform, and survive a cataclysm, or "avalanche" in the terms of the SOC theory. A system in the SOC state is a stone that has managed to climb to the top of the hill by itself and somehow stays there, perhaps not in perpetuity, but still for quite a long time.

The behavior of the SOC system is strongly influenced by nonlinear effects such as the aforementioned disproportions of causes and effects. Moreover, these nonlinear effects occur within such a system in a natural manner, under the influence of quite ordinary, that is, subjectively insignificant or routine events. The mechanisms that provide such a fine self-adjustment of the system are the combination of fast relaxation and the slow growth of stress (Podlazov, 2001, pp. 16–17). The apparent stability in this case is one side of the system, while a catastrophe is the other. Such a catastrophe does not require any extraordinary, strong or new factor, whether external (e.g., a falling meteorite) or internal (e.g., the hardships of war and class struggle).

So-called avalanches sometimes occur in self-organized critical systems. Avalanches are very fast and large-scale jumps in system parameters. Representatives of various sciences focus their attention on this phenomenon:

> In subject-specific research, avalanches are usually identified with abrupt qualitative transformations and even catastrophes: strong earthquakes and large floods, mass extinctions of biological species, huge traffic jams, etc. It should be emphasized that ordinary—even routine—micro-level processes can lead to avalanches. Because such processes have not caused any catastrophic consequences for a long time in the past, observers tend to consider them

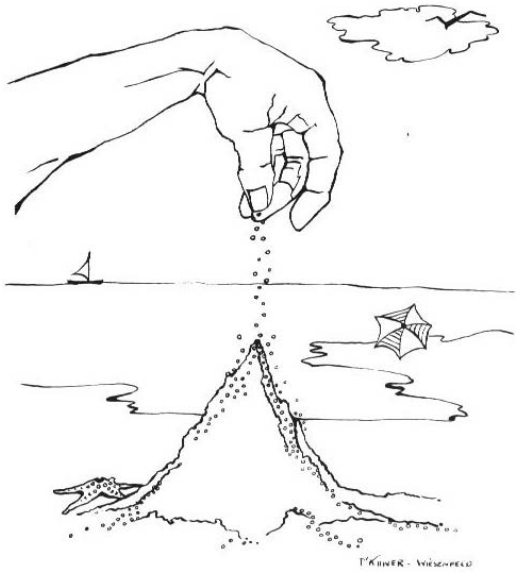
> harmless and even insignificant. Therefore, an avalanche for an observer may seem unexpected, causeless, coming from nothing. Of course, for extraordinary large-scale events, historians might come up with extraordinary large-scale causes ex post facto, while contemporary observers quite often assign responsibility for an avalanche to foreign agents, supernatural forces, conspirators, secret organizations, and so on. An avalanche, however, is a legitimate immanent product of a self-organized critical system. (Zhukov, 2022, pp. 164–165)

Only systems that have the necessary properties and structure are suitable for the emergence of SOC. Such specific systems must be comprised of a vast array of components, and a distinct possibility of feedback loops is required. The system itself must be on the verge of integrity; in other words, its components should have both autonomy and the ability to establish numerous connections to behave as a whole. Such requirements for candidates for critical systems might seem unusual for representatives of some natural sciences, but not for humanities scholars. After all, most social systems, that is, systems created by people and consisting of people are exactly as described above.

The key model of the SOC theory is a sandpile, as seen in Figure 2. Yet, it must be noted that a real sandpile on the beach will most likely not demonstrate the intended behavior due to, for example, humidity. For the experimental demonstration of the theory, it is better to use a pile of polished rice in a laboratory than sand on the beach (Bak, 1996), though a sandpile has already become a trademark of the SOC theory.

Figure 2

The Sandpile Is a Central Heuristic Metaphor of the SOC Theory



Note. Drawing by E. Wiesenfeld. Source: Bak, 1996, p. 2.

Under the conditions of the experiment, a few grains of sand are constantly added to the center of the pile. However, not all of the grains will immediately roll down to the foot of the pile, since the slope of some sections is not steep enough, i.e., not critical. A slight but regular trickle of sand grains that are poured onto the top, meaning a build-up of tension causes landslides, or relaxations, of various sizes, during which the slope of the sections of the pile becomes once again not steep enough. Landslides come in all sizes, including the smallest shifts, medium-sized events, and revolutionary avalanches that involve large sections of slopes. The size distribution of landslides—the number of grains of sand involved—is determined by a power law.

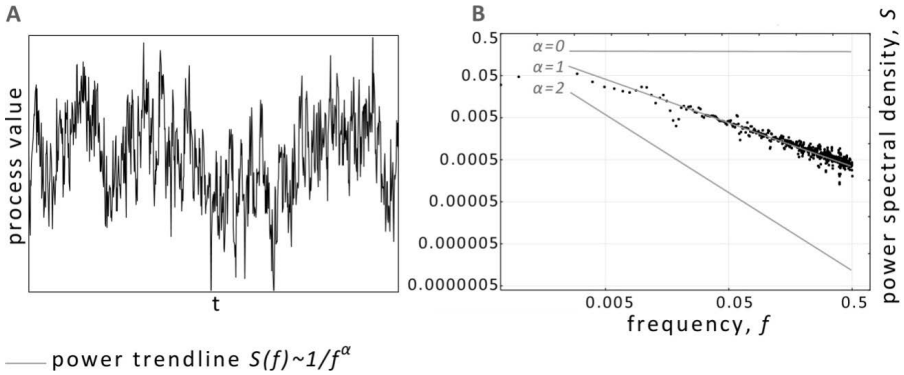
In one of my works, I tried to show the similarity between the human act and the fall of a grain of sand:

> An avalanche … is triggered by a single grain of sand, which can cause a minor collapse of the slope in a local, highly-inclined, area. This collapse causes the sand to slip in adjacent areas if they also slope too much. This self-reinforcing process develops rapidly. Of course, there was nothing special about that particular grain of sand. It played a historical role only insofar as the system as a whole was in a critical state: the minimally stable areas (i.e., the areas with a large local slope) almost constituted a coupled cluster. One grain of sand—a single weak impact—was enough to make the system (slope) act (collapse) as a whole. (Zhukov, 2022, pp. 165–166).

Systems generate various signals, such as time series—for example, a record of how the main parameters change over time. Within SOC systems, many micro- and macro-events trigger causal chains that combine, weakening and strengthening one another. Such combinations form a specific signal called pink noise (1/*f* noise), which is an attribute of SOC. It is important that pink noise can be detected (Figure 3).

Figure 3

Specimen (A) and Spectrogram (B) of Pink Noise



Note. Source: Zhukov et al., 2020.

One of the founders of the SOC theory, Per Bak, wrote the following:

> A phenomenon called 1/*f* (one-over-*f*) noise has been observed in systems as diverse as the flow of the river Nile, light from quasars … and highway traffic. … There are features of all sizes: rapid variations over minutes, and slow variations over years. ... The signal can be seen as a superposition of bumps of all sizes; it looks like a mountain landscape in time, rather than space. The signal can, equivalently, be seen as a superposition of periodic signals of all frequencies. This is another way of stating that there are features at all time scales. Just as Norway has fjords of all sizes, a 1/*f* signal has bumps of all durations. (Bak, 1996, pp. 21–22)

Increasingly, researchers are coming to the conclusion that punctuated equilibrium is, as a rule, pink noise. Furthermore, the explanation of this phenomenon can and should have a universal, interdisciplinary character (Podlazov, 2001, pp. 7–8).

This is how Malinetskii describes the phenomenon:

> Punctuated equilibrium, which is observed in the process of biological evolution, in the functioning of social and technical systems. A typical situation is when nothing noticeable happens for a very long time, and then rapid changes radically change the shape of the system, the time of revolutions comes, which, of course, does not negate many small events that we simply do not notice. (Malinetskii, 2013, p. 39, transl. by Dmitry Zhukov [D. Zh.])

As mentioned above, the rapid expansion of the SOC theory in various disciplines was precisely due to the fact that it provided the satisfaction of an acute heuristic need to interpret punctuated equilibrium that raises a large number of intriguing and significant research questions. In previous works, I have outlined some of these questions:

> "Jerks" and "jams" in the course of forced modernization in history, modern protest movements, bursts of terrorist and extremist activity, mass hysteria, and mass infatuation—these and many similar changes can proceed rather quickly and can, in many cases, be non-linear. At first glance, socio-political activity in a number of cases increases spontaneously: insignificant causes grow quickly in the information sphere to become "sufficient reasons" to overthrow political regimes. Some revolutions in recent years did not have a clearly defined preparatory stage or well-observed socio-economic prerequisites. Even institutional transformations can be multivariate and contain phase transitions, and in some circumstances, they depend on weak and even random influences. Of course, this is not a complete list of the oddities that can be viewed as manifestations of punctuated equilibrium in social systems. (Zhukov, 2022, p. 164).

The SOC theory demonstrated the connection of low-level processes with global events. It also described the mechanisms by which system-wide regularities can

be generated by a vast array of decentralized and uncoordinated "minor" ordinary events, that is, interactions between micro-communities and minuscule, fundamental elements of the system. As regards a social system, people should be considered such elements. This means that social macro-dynamics, from the point of view of the SOC theory, is brought about by the actions and behaviors of individuals.

An important advantage of the SOC theory is that it defines clear numerical criteria for identifying those systems that are in a state of SOC. At the moment, one of the works that have set a benchmark for, among other things, the methodology for identifying SOC in social processes is a study by A. Dmitriev and V. Dmitriev published in the journal *Complexity* (Dmitriev & Dmitriev, 2021).

To identify SOC, several steps are required, including examining the time series generated by a system for the presence of pink noise. There are some other criteria, such as autocorrelations in the mentioned time series and power laws (with a certain exponent) in the distribution of results or system properties.

The problem with the social sciences and humanities is quite often that the amount of data suitable for identifying SOC is limited. However, this does not make research futile, as some methods are also available for relatively small amounts of data. At the same time, it is important to understand the extent to which such an analysis can be categorical.

The common research design used in most of the works on SOC in the social sciences and humanities can be described as follows. First of all, similar data are tested for the presence of SOC indicators. This is a purely mathematical part of research, as signs of SOC are identified or not as a result of formal computational processes. For example, when looking for pink noise, it is best to subject the original time series to spectral analysis and to calculate the power law exponent in power spectral density if a power law is found there. An indicator in a certain range around 1 makes it possible to identify the series under examination as pink noise.

Then, the nature of the system, its state, and regularities in its development are interpreted by referring to the universal explanatory schemes of the SOC theory or to models that, as it is known from computational experiments, are capable of simulating SOC, for example, the sandpile model, the Bak–Sneppen model, the forest fire model, or the interface growth model (Bak, 1996; Biggs, 2005; Cederman, 2003; Podlazov, 2001; Roberts & Turcotte, 1998). Qualitative interpretation involves linking the known properties of the system with abstract notions and concepts of the SOC theory. In many cases, the discovery and recognition of the fact that at least, in some periods SOC can be inherent in the system under examination makes it possible to answer many intriguing questions related to effects that previously seemed anomalous.

Literature Review

In the late 1980s, a classic paper on the SOC theory was published (Bak et al., 1988). Bak's book, quoted many times in this article, was firstly published in 1996 and had the effect of a spark in a dry steppe (Bak, 1996). In the works of the founders of the SOC theory, the application of the new conception in the public sphere was conceived of as inevitable. However, such confidence was not immediately confirmed by case

studies in the social sciences and humanities. In the late 1990s, Roberts and Turcotte (1998) were finally able to prove the presence of SOC in social reality, namely, in the system of international relations that generates military conflicts. Roberts and Turcotte demonstrated that the new approach gives rise to proper social knowledge and leads to some very important—perhaps even strange—conclusions. Later on, power laws, that is, signs of SOC were found in some social phenomena, such as wars and internal conflicts (Biggs, 2005; Cederman, 2003). In 2001, Podlazov, a disciple of G. Malinetskii, successfully defended his doctoral dissertation in mathematics titled *Novye matematicheskie modeli, metody i kharakteristiki v teorii samoorganizovannoi kritichnostii* [New mathematical models, methods and characteristics in the theory of self-organized criticality] (Podlazov, 2001). In this dissertation, he made many elegant observations regarding the applications of the ideas of SOC to the clarification of social research problems, though that was not his main objective.

However, case studies were still quite rare. In the early 2000s, theoretical thought continued to develop, despite the fact that it did not have a solid empirical foundation. Conviction in the heuristic value of the SOC theory and its interdisciplinary potential was fueled by large-scale successes in the natural sciences, which partially compensated for the lack of evidence in the social sciences.

Among the theoretical works of the 2000s on SOC in social reality, a series of publications by Brunk (2000, 2001, 2002a, 2002b), occupies a special place. Mention should also be made of an article by Kron and Grund (2009), who, despite not having presented specific calculations, supported the idea that many sociopolitical processes, such as the arms race, are manifestations of SOC.

The situation fundamentally changed in the 2010s when the accumulation of empirical data—namely, proven effects of SOC in social reality—and their interpretations accelerated many times over. The works of Malinetskii (2013), a supporter of the interdisciplinary applications of synergetics, were of great importance for the start of this new stage of SOC expansion. The scientific community of the social sciences and humanities also heard Borodkin's call to pay attention to the heuristic potential of SOC for historical research in particular (Borodkin, 2005, 2019). One of the most extensive multidisciplinary research programs aimed at detecting and interpreting SOC in various sociopolitical, including historical processes was carried out at the Center for Fractal Modeling (Barabash & Zhukov, 2018, 2020; Zhukov et al., 2016, 2017, 2020). The studies by A. Dmitriev and V. Dmitriev (2021) were already mentioned above. Significant and spectacular results were obtained in the research by Picoli and colleagues (2014), Shimada & Koyama (2015), and Thietart (2016). One breakthrough was the publication of fundamental research by Tadić and colleagues (Tadić et al., 2017; Tadić & Melnik, 2021), who were able to demonstrate that knowledge generation by human communities can be carried out in the SOC mode. Furthermore, several works were published in the late 2010s and early 2020s (Açıkalın & Artun, 2019; Gromov & Migrina, 2017; Krafta & Bortoluzzi da Silva, 2020; Leydesdorff et al., 2018; Lu et al., 2021; Malkov et al., 2018), which indicates that this research line is gaining supporters rather than fading.

Itemizing the domains of knowledge in which SOC has been found in the presented works provides a very extensive list that includes rebellions and civil

unrest (historical and modern), protest movements and social conflicts, activity (including political) of users of social networks, wars and other international conflicts, extremism and terrorism, criminal activity, demographic processes, corporate governance and corporate evolution, electoral behavior, urban development dynamics, and even citations of scientific articles. This list, while incomplete, corresponds to the spirit of the SOC theory, which, according to one of its founders, Bak, is applicable to many subjects, from the intensity of the luminosity of stars to the activity of the human brain (Bak, 1996).

Of course, while not all of the areas listed above are entirely under the effect of SOC, it is possible to know for sure that criticality is indeed there, and this fact can greatly affect the classical explanatory schemes. Perhaps the main conclusion that this brief review of the literature should lead to is that SOC has won the right to be an important part of social reality.

Question One

Is SOC really a ubiquitous property of social reality? The founders of the SOC theory insisted that it is a widespread, but not unique, phenomenon found in everyday life. This conviction stemmed from the natural idea that physical, technical, biological, social, and any other systems are identical in their fundamentals. Laws of nature, if they are the most fundamental laws, are the same for everyone. At the same time, the scope of any theory has limitations, and, therefore, an object, before being interpreted in the spirit of the SOC theory, must be tested for the presence of criticality markers by means of well-defined, formal methods.

What is the situation like in the social sciences and humanities with the search for the limitations of the SOC theory? Brunk (2000, 2001, 2002a, 2002b) seemed to express the most optimistic view on these limitations, and his thinking was bold and inspirational. His contribution to the propagation and legalization of the SOC theory in the social sciences and humanities is obvious. This, of course, does not change the fact that some of his statements are polemical in nature. It should be noted that at the time that Brunk wrote his famous series of works, empirical data existed only in a few publications, and it was hardly possible to judge the breadth of SOC's distribution on the basis of facts. Most importantly, Brunk stated that all human societies have a tendency toward SOC, that SOC is the engine of history, and that all major social cataclysms (revolutions, crises, and so on) should be considered precisely as avalanches in line with the SOC theory.

Here is an extensive quote that shows the logic and power of Brunk's arguments:

> Our common sense tells us that the most important things should be the easiest to predict, but wars, market collapses, revolutions, cabinet dissolutions, and many other important events frequently occur without warning … What has become clear in the last decade is the reason that our standard models do not predict historical events of great consequence is that our traditional notion of causation is incorrect. In a linear world, the magnitude of a cause is always

> proportional to the magnitude of its effect, and so the big events of history "must have had" big causes. In a nonlinear world, the smallest of triggers can produce large effects, and so the relationship between cause and effect is no longer what we have assumed … It is far more likely that all human interactions are generated in part by the only other sort of nonlinear dynamic yet discovered: self-organized criticality. Self-organized criticality is such a simple process that it probably is ubiquitous in human affairs, and is what produces fractal time series of historical data. (Brunk, 2002a, pp. 25–27)

> This is the source of "outliers" in historical data. If the world is a SOC environment, then our assumptions about how to deal with these "outliers" have been wrong. Instead of the bulk of the data being produced by one process and the "outliers" by another, all events—both the minuscule and the historically monumental—are produced by the same process in a SOC environment. (Brunk, 2002a, p. 31)

> Statistical "outliers" are now seen as the great events of history that will appear in all samples of SOC data, and self-organized criticality becomes the "engine of history" that generates its most important events. (Brunk, 2002a, p. 36)

Realizing that it is not possible to detect signs of SOC in all historical processes, Brunk argued that, in many cases, a state of criticality is not in its pure form. Instead, it is rather vague and, as he put it, weak (Brunk, 2002a).

Indeed, as emphasized above, human communities are a very favorable environment for SOC. Communities consist of people who more or less freely communicate with each other and create, among other things, feedback loops. Communities usually experience problems associated with the accumulation of contradictions that require resolution, that is, relaxation. In addition, it is worth noting that many social cataclysms do not have a marked preparatory period and, in this regard, are similar to avalanches in line with the SOC theory.

However, by and large, the available data does not confirm that SOC is integral to human society and history. SOC is not necessarily always identified, as in the case of some historical and modern time series (Barabash & Zhukov, 2018, 2020; Zhukov et al., 2017, 2020). Furthermore, an attempt to circumvent this fact by referring to the existence of "weak" and, therefore, poorly detectable SOC systems run into Occam's razor. If some systems do not manifest themselves clearly enough as SOC systems, maybe these are something other than "weak" SOC systems.

On the other hand, the available evidence is not sufficient to reject Brunk's claims. As a matter of fact, it has been well established that many historical processes, including those in the preindustrial era, fit into the SOC theory.

For example, the work of Lu et al. (2021) seems to cover the longest time span and deal with the basic dynamics of society and the state in Chinese history:

> The rising and falling of empires follow the self-organized criticality rule … The more sand particles added may lead to large-scale collapse or even a series

> of chain reactions, which is similar to the chaotic falling of empires. When the social problems accumulated to certain degrees, a small crisis may result in the collapse of the existing empires … The solid life cycle pattern of empires in history is persistent and stable, which, therefore, can be explained by the self-organized criticality and investigated by the sandpile modeling and simulations. (Lu et al., 2021, pp. 12–13)

Here are some examples from my works. In collaboration with fellow historians, I discovered criticality in the dynamics of peasant revolts in some governorates from the second half of the 19th century until the first Russian revolution. I assumed that in those communities that demonstrated criticality, there had been some internal potential for large-scale uprisings. This means that inside, at the micro level, these communities had a certain source of constant tension, which from time to time was relieved through separate local protests and which, eventually, could generate an avalanche, or, in other words, a major riot. I found that not all governorates demonstrated SOC. That is, some regions had not reached this state, while others, on the contrary, had passed beyond it (Zhukov et al., 2017).

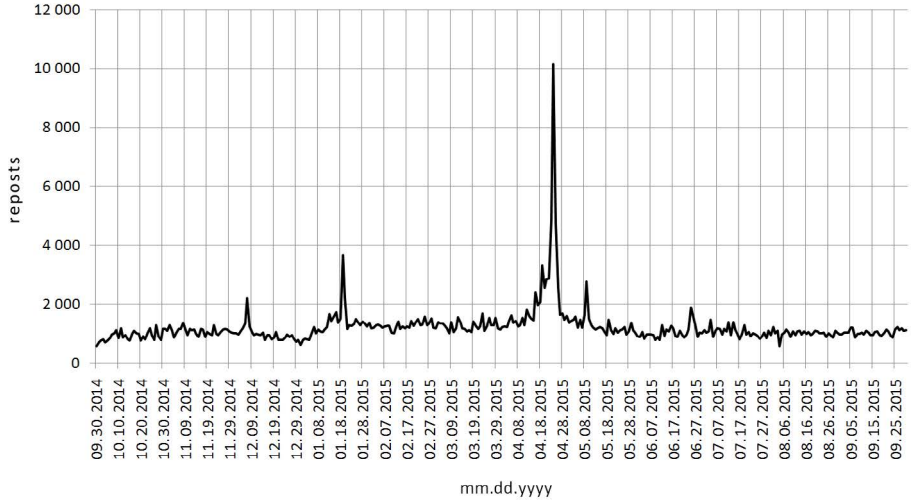
Similar results were obtained for rebellious activity in Russian cities in 1917–1918 during the February and October Revolutions and in the subsequent period. The capital cities of Moscow and Petrograd generated SOC. At the same time, urban communities in many other regions exhibited chaotic behavior (Zhukov et al., 2017). In the research, performed jointly with fellow historians including myself, Kanishchev interpreted the emergence of pink noise in the demographic dynamics of peasant communities in the 20th century as a manifestation of the transition to partial regulation of demographic indicators (Zhukov et al., 2016). It is impossible not to notice how diverse the manifestations of punctuated equilibrium, pink noise, are in the dynamics of social systems.

It is fair to assume that SOC is an essential characteristic of societies that, for some reason, are in a borderline state, that is, on the verge of transformation. Moreover, since modern societies are characterized by a higher density of communication and speed of interaction, it is reasonable to expect that the effects of SOC will grow stronger as the world enters modernity and then postmodernity. In addition, many social and political processes in the modern world take place in virtual reality (Volodenkov & Fedorchenko, 2021), which, by definition, has a very strong tendency toward SOC. Indeed, SOC markers are found in abundance in modern processes, even those that seem “normal” and do not have transformational potential.

In several works, I considered the emergence of SOC in politicized online communities as a reliable indicator of their political mobilization. People in such communities are connected by numerous channels of reflexivity, and they are involved in common activities and discussions. In a state of criticality, a community can generate information avalanches, or bursts of information, that an outside observer does not expect (for example, Figure 4).

Figure 4

Information Avalanche in the VK-Communities That Supported the Political Movement Known as "Electric Yerevan"



Note. Source: Zhukov et al., 2020.

Such information avalanches not only initiate a change in virtual opinions, but also incite violence. In this vein, I explored the activity of a number of communities on VK[1] and Facebook[2] during the impeachment of Brazilian President Dilma Rousseff (Figures 5 and 6), in Armenia during the Energy Maidan and the Velvet Revolution, in Russia during the Navalny rallies in early 2021, and in Germany and France during the Yellow Vest protests (Barabash & Zhukov, 2020; Zhukov et al., 2020).

In the cited work by A. Dmitriev and V. Dmitriev (2021), a state of SOC was also considered a sign of a highly mobilized community. In particular, the researchers studied Twitter[3] activity during the US presidential debates and revealed the periods and mechanisms of criticality formation.

Despite the high prevalence of SOC effects on the Web, many works have shown that virtual communities, as well as real groups, organizations, institutions, and countries, are not always in a state of SOC. Thietart (2016) studied the reform activity of Danone Corporation, dividing the period under examination into several subperiods and only finding SOC in some of them. Thietart concluded that the accumulation of experience and demands for transformation probably needs to happen, after which the system should enter a state of SOC, a state in which system has a tendency toward transformations of all scales.

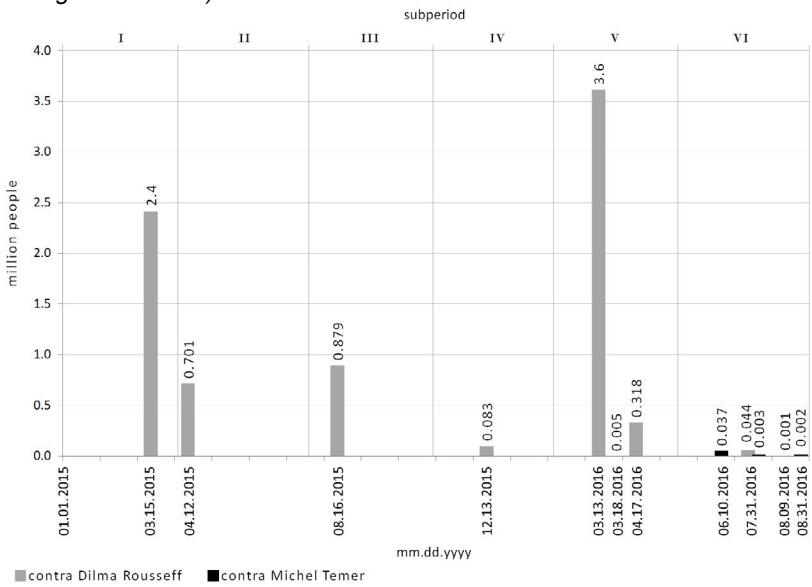
[1] VK (short for its original name VKontakte) is a Russian online social media and social networking service. https://vk.com VK™ is a trademark of VK.com Ltd.

[2] Facebook™ is a trademark of Facebook Inc., registered in the U.S. and other countries. По решению Роскомнадзора, социальная сеть Facebook в России признана экстремистской организацией и заблокирована.

[3] Twitter® is a trademark of Twitter Inc., registered in the U.S. and other countries. По решению Роскомнадзора, социальная сеть Twitter полностью заблокирована в России.

Figure 5

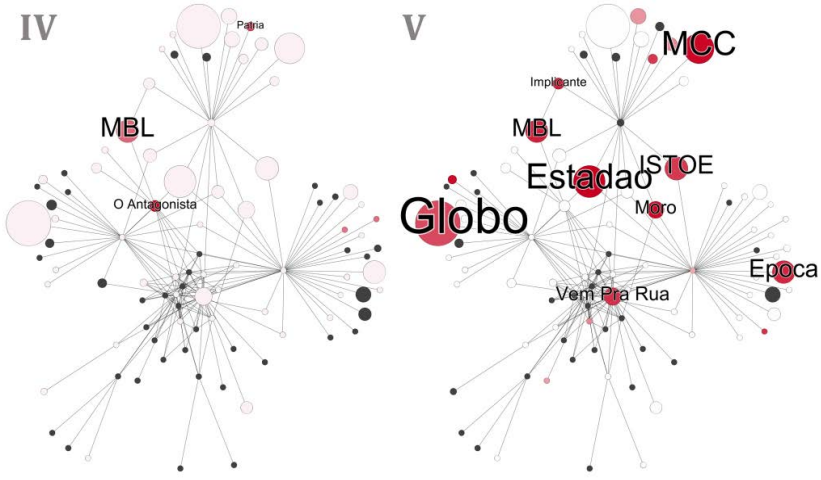
The Number of Participants in the Protests Against Dilma Rousseff and Michel Temer (According to the Police)



Note. Source: Zhukov et al., 2020.

Figure 6

Pink Noise in the Network During Subperiods IV (October 28, 2015 to February 4, 2016) and V (February 5, 2016 to May 14, 2016) (Brazil, Facebook[4], Communities Protesting Against Dilma Rousseff)



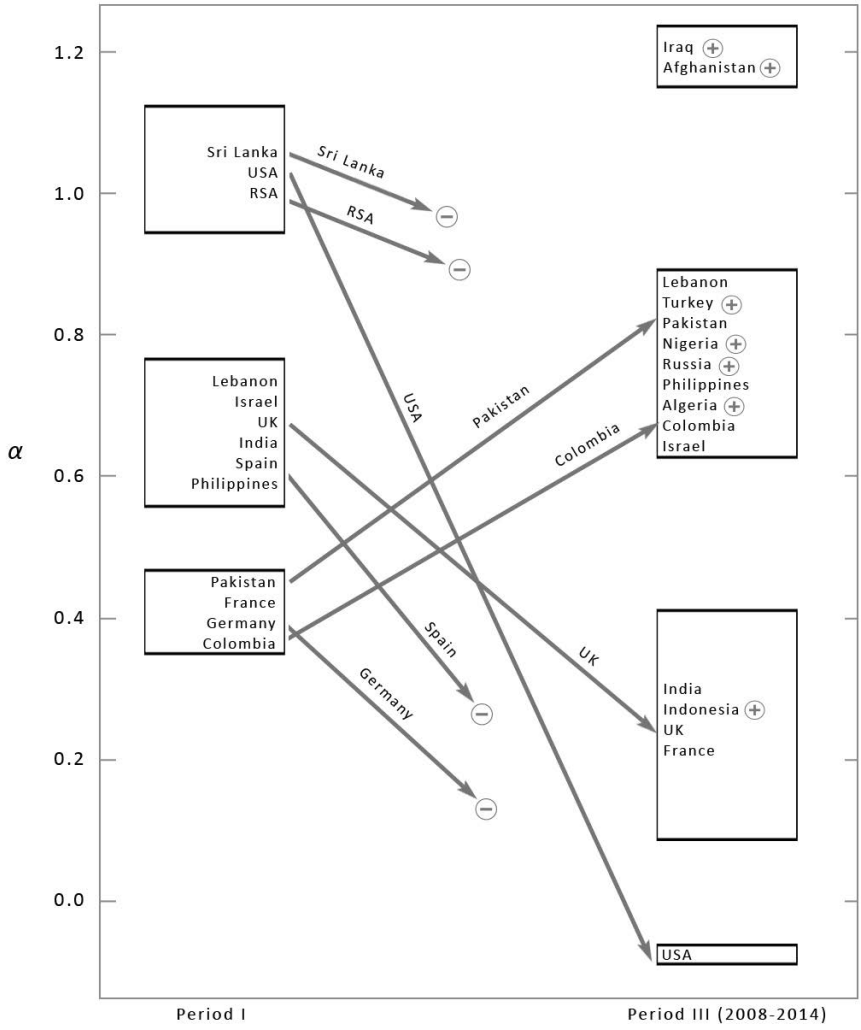
Note. Source: Zhukov et al., 2020.

[4] Facebook™ is a trademark of Facebook Inc., registered in the U.S. and other countries. По решению Роскомнадзора, социальная сеть Facebook в России признана экстремистской организацией и заблокирована.

I also studied time series suggesting terrorist activity over the past few decades in 20 countries around the world. Pink noise was only found in some series and countries and for some time intervals (Figure 7): "'Pink' societies have inherent system potential for a significant rise in the number of terrorism events … Any reduction in law enforcement may lead to a rapid upsurge in terrorism" (Barabash & Zhukov, 2018, p. 9).

Figure 7

α-Based Clusters From the 1970s to the 1990s (Period I) and From 2008 to 2014 (Period III)



Note: α is the power law exponent. Some countries were added (+) or removed (–) following the rise or disappearance of terrorism as system-wide phenomenon or changes in statistics. Source: Barabash & Zhukov, 2018.

Brunk's hypothesis that all social cataclysms are avalanches in line with the SOC theory is especially noteworthy. Indeed, the great advantage of this theory is that it does not make the researcher search for some powerful, extraordinary factors to explain large-scale events. The theory derives both everyday incidents and global upheavals from micro-level processes and states. This is a very productive approach, but only if it is possible to identify the presence of SOC clearly. Moreover, the theory itself in no way denies the presence of some powerful, extraordinary factors in nature; rather, it only makes them optional. For example, in July 1601, in Moscow, there were frosts, and in September of the same year, it snowed. Something similar happened over the next two years. It was one of the manifestations of the Little Ice Age in Europe. The Time of Troubles coincided with the period of crop failures and, consequently, famine. Occam's razor forces one not to interpret the Russian state as a weak SOC system, but to admit that the climate factor, coupled with political and social contradictions, initiated a systemic crisis of society and the state.

However, such traditional schemes cannot explain some revolutions, uprisings, dissolutions of states, wars, and other social cataclysms that occur without a visible period of preparation. In this case, the SOC theory is certainly an excellent tool, as it forces the researcher to refocus their attention from searching for "strong" reasons to diagnosing the state of a system as a whole—that is, they must consider a system's structure and principles of functioning, the processes of stress accumulation, and "bursts" of relaxation.

In summary, Brunk's concept of history has not yet been confirmed or rejected over the past two decades. It has been found that SOC plays a key role in the behavior of communities at key moments in their history. Furthermore, SOC has shown itself to be an important, yet not a ubiquitous (judging by the current state of research) property of social reality. At the same time, it seems that there is still a chance of obtaining ample confirmation of Brunk's statements, especially in relation to modern history. Ignoring SOC in social reality leads to a more serious distortion of the truth than an overzealous search for criticality where it may not exist.

Question Two

Does the SOC theory really substantiate the fundamental unpredictability and inevitability of social catastrophes? It is quite likely that such an opinion was formed as a result of an interdisciplinary misunderstanding, that is, insufficient knowledge of the empirical side of the social sciences and humanities. However, there is a good reason for this question to appear.

The SOC theory, indeed, cannot accurately predict the date and location of avalanches. Large-scale fluctuations in time series represent a numerical sign of social cataclysms. In an avalanche, the quantitative indicators of a system always go beyond the scope of what is considered normal and, possibly, beyond the scope of viability. Therefore, an avalanche, as a rule, is associated with the destruction and qualitative transformation of the system.

Since an avalanche, like any other landslide in the sandpile model, can be initiated by a single grain of sand (i.e., a minor triggering event), it is almost impossible to predict which grain of sand will play this role. This is not only due to the incompleteness of knowledge: the universe itself, perhaps, does not know, or is dimly aware of, which particular grain of sand is destined for a historical role. The beginning of an avalanche can vary significantly due to nonlinear effects.

In a hypothetical world where SOC reigns supreme, the cause of all major (and minor) disasters would be the very state of society, and all of the apparent causes—that is, the events preceding in causal chains—would, in fact, be triggers. The problem is that the universe, both hypothetical and real, creates many triggers "out of thin air." After all, anything can be a trigger, and such an "anything" appears quite often. Any snap of the fingers can grow into a universal catastrophe because this is a very fragile world, which Bak calls "Sandpile World":

> Once the pile has reached the stationary critical state, though, the situation is entirely different. A single grain of sand might cause an avalanche involving the entire pile. A small change in the configuration might cause what would otherwise be an insignificant event to become a catastrophe … Parts of the critical system cannot be understood in isolation. The dynamics observed locally reflect the fact that it is part of an entire sandpile. … In the critical state, the sandpile is the functional unit, not the single grains of sand. No reductionist approach makes sense. The local units exist in their actual form, characterized for instance by the local slope, only because they are a part of a whole. (Bak, 1996, pp. 59–60)

However, human history, even contemporary history, only partly matches this exaggerated description. In social reality, there are islands and even, perhaps, continents of linearity and other "straightforward" regularities. SOC does not emerge always and everywhere, yet where it does emerge, it fundamentally changes the behavior and development of systems. The problem is that people cannot see with the naked eye when events cease to be "usual," and processes begin to be influenced by nonlinear effects. As Brunk writes, "this example illustrates a common problem when investigating nonlinear historical and spatial processes. They often masquerade as something that they are not until a very great deal of data can be examined" (Brunk, 2002a, p. 40).

The potential for an avalanche is inherent to an SOC system: it is hidden in plain sight from the observer. For a long time, such a potential does not produce any effect; routine events become the norm and are perceived as part of stability. But that kind of stability is an illusion. An avalanche can emerge all by itself from nothing. In other words, SOC systems can react very strongly to insignificant triggers, even though they may have disregarded similar triggers for a long time. It is vital that the causes of cataclysms (provided that they are actually avalanches) be sought not in tremendous, abstract, controlling forces, but in the state and structure of the system itself, in the nature of routine interactions, including the everyday practices, needs, and opinions of people.

However, researchers, including historians, have tended to rationalize major unexpected events after the fact, seeking and finding sound reasons, strong factors that have been previously hidden, and so on. Since people mainly encounter linear dependencies on a daily basis, they intuitively attribute them to the entire universe. However, rather than being a reflection of the properties of the universe, this is a manifestation of the principle of economy behind the observer's reasoning. Major events, outliers in time series, are often dismissed by researchers as anomalies (i.e., instrumental errors or exceptional, unnatural events caused by forces not inherent in the system itself). The traditional view of social cataclysms is that when dealing with special events, one should search for special causes. The SOC theory requires looking for trivial causes for special events if such special events took place in a critical environment.

The tools of the SOC theory are able to distinguish critical systems from noncritical ones and show exactly which system entered the avalanche-prone period and when. In particular, the appearance of pink noise in time series indicates an SOC system, where power laws prevail. Although the date and place of an avalanche or social cataclysm are unknown, the predictions of the SOC theory are of high practical importance for the social sciences and humanities. Such predictions, in essence, are no different from a body of predictions in natural science, which also have a probabilistic and variable character.

Thus, the SOC theory makes it possible to diagnose—not only after the fact, but also in advance—the transformational potential of a social system, from an online community to a social group and the whole of society. Such heuristic capabilities of the SOC theory were confirmed by case studies (Zhukov et al., 2017, 2020). However, somewhat earlier and, apparently, for the first time in the literature on the sociopolitical applications of SOC, this idea was put forward by Shimada and Koyama (2015). Using the materials of Japanese electoral statistics for several decades, Shimada and Koyama indicated that the presence of power law distributions with an exponent of about 1 in the time series reflecting political life can be an indicator of the readiness of certain social groups for a qualitative (i.e., radical) political transformation.

The latter part of Question Two concerns the inevitability of social cataclysms. Indeed, the SOC theory considers avalanches a natural manifestation of the laws of nature. This sometimes becomes a source of pessimism for researchers who see normal historical processes as exceptionally straightforward and progressive. On the other hand, many researchers view transformational leaps as necessary phenomena. So, Shimada and Koyama foresee an era of change in Japan:

> As indicated by the fallout from the Lehman collapse and the severe deflationary economic downturn in Japan, the buildup of discrepancies in the basis of Japanese society is reaching an extreme level. In order to break free from this stagnant era and open up future prospects, new strategy for social change is needed. Currently, the country is approaching a dramatic transition from the state of social change that has existed up until now (exponent $D_M = 1.27$) to a state of real criticality, the most probable for social change ($D_M = 1$). The model suggests that a decrease

> of the power exponent D_M (1.27) changes the agonistic structure greatly, leading to an increase in the change output *R.* (Shimada & Koyama, 2015, p. 348)

However, the fact that there have been dramatic social transformations of various scales occasionally called quantitative and qualitative leaps, or phase transitions, throughout history is old news. Revolutions seem inevitable for almost all scholars of the social sciences and humanities, except maybe early positivists.

Is it possible to prevent a cataclysm provided it is an avalanche in line with the SOC theory? If artificially preventing some section of the slope of the sandpile from collapsing, then this will make the slope in this section steeper. If repeating the same operation several times in different areas, the prospect of a superavalanche will arise sooner or later, since the slopes of the pile will become too steep. Manual control will help delay the onset of the catastrophe but aggravate its course.

Thus, Bak draws disappointing conclusions regarding an economy:

> Our conclusion is that the large fluctuations observed in economics indicate an economy operating at the self-organized critical state, in which minor shocks can lead to avalanches of all sizes, just like earthquakes. The fluctuations are unavoidable. There is no way that one can stabilize the economy and get rid of the fluctuations through regulations of interest rates or other measures … If economics is indeed organizing itself to a critical state, it is not even in principle possible to suppress fluctuations … But maybe, as we shall argue next in a different context, the most efficient state of the economy is one with fluctuations of all sizes. (Bak, 1996, pp. 191–192)

Apart from very large systems, such as an entire society, SOC can be extinguished in a particular system by fragmentation or by the elimination of the source of activating impulses—that is, the source of tension. It is clear that it is virtually impossible to control SOC systems by conventional methods because they have low sensitivity to traditional control measures (Podlazov, 2001, p. 34).

The historical causality of social transformations does not always mean that they must take on the form of social catastrophes in the literal sense of the word. In fact, historical necessity in many cases leaves a significant amount of room for people to choose the format of transformations. It is not so much the avoidance of cataclysms that is important, but their format—that is, the ratio of cost to benefit, as well as the formation of a new system thereafter. To control, at least partially, the results of radical transformations, it is necessary to understand their nature.

Question Three

What contribution can the SOC theory make to clarifying the fundamental mystery of the relationships between chance and regularity and between human will and historical necessity? For quite a long time, there was (and, in a sense, still is) the notion that there is an impenetrable barrier separating the mathematized natural sciences on

one side and the social sciences and humanities on the other. In most cases, it is allegedly impossible to extend the theories and methods of the natural sciences to the social sciences and humanities, and vice versa. The essence of this barrier lies in the distinctive nature of the subject matter of human sciences, which is fully derived from free will, that is, the capacity of a person to act in spite of the circumstances, with no regard to scientific laws.

However, as it turned out, the objects of the natural sciences (for example, atoms) are also capable of "acting" rather arbitrarily. Thus, the half-life of uranium-235 is approximately 700 million years: over this time, about half of the atoms from the initial amount of uranium will have decayed. Still, a particular atom may decay in one second or in 10 billion years. Of course, an atom does not make a decision, but the relationship between an "action" of an atom and the general evolution of uranium-235 can be described in the same way as the relationship between human action and historical regularity.

Moreover, it became clear that the objects of the natural sciences are capable of self-organizing, sometimes in the most paradoxical manner. It is unlikely that they negotiate like people, but the principles of self-organization turned out to be universal. Finally, many systems, regardless of their nature, demonstrate purposeful behavior and persistently move toward some attractor, whereas people, inspired by dreams and ideas, pursue their goals. One unique attribute of the social sciences and humanities now lies in the fact that principles of ethics and morality can be applied to the subject of these disciplines: people. At the level of explanatory schemes, there are no differences anymore. As I discuss later, this dramatic convergence of different branches of knowledge happened not because man was "mathematized," but because, in order to explain nature, natural science and mathematics had to develop concepts that were progressively more "humanized", that is, progressively more suitable to explain not only inanimate matter, but also social phenomena.

Of course, such an evolution of the paradigms of natural science was not inspired by the desire to claim the domain of the social sciences and humanities. Since around the end of the 19th century, the evolution of the exact and natural sciences has been strongly influenced by the problem of the relationship between regularity and chance. The SOC theory has become an important, logical, and now final link in this evolution.

Manifestations of free will, such as an act, opinion, or decision, in interdisciplinary explanatory schemes can be interpreted precisely as an accident, an essentially unpredictable event. What is more, such an accident is local in time and space and low energy. Nonetheless, such accidents emerge in multitudes, always and everywhere. How does such a reality, both physical and social, function?

The starting point of my brief review of this question is Laplace's determinism, which has dominated since the 18th century and argues that the entire universe is determined at all times by chains of cause and effect (Laplace, 2007). Causes and effects are unambiguously connected: each cause gives rise to a strictly defined effect, and each effect must have a strictly defined cause. The chains are unbreakable, and there are basically no coincidences. Those phenomena that seem random are in fact determined by a regularity that has not yet been understood. All systems are

similar to clockwork mechanisms: the behavior of all elements is predetermined by the structure and rules. In such a picture of the world, the free will of a person could be present only as an exception to the rules—that is, as a reflection of the Divine. Consequently, social research, if it was focused on arbitrary human behavior, was doomed to marginalization into the nonrational sphere of art and religion.

A huge breach in this picture of the world was made by scientists' realization by the end of the 19th century that a significant part of the laws of the physical world are statistical laws. Laws of this type determine the behavior of the entire system, but they are not binding to individual elements, which may behave randomly. An example of this kind was given above: the half-life law does not in any way determine the behavior of each particular atom, but it is strictly obeyed by the entire set of atoms. The development of ideas about statistical laws was associated with the emergence of concepts of probabilistic causality.

Within the framework of such ideas, the existence of chance was recognized, but the significance of chance—and, consequently, human decisions—was reduced to a minimum: chances and people did not influence the course of events, which was determined by an objective, "extrahuman" regularity. Statistical laws were adopted by the sociologists of that time who recognized that a person is free to commit any act and have any opinion, while the overall group behavior, as well as the development of institutions, society, states, and so on is beyond the control of a particular person or even the entirety of people.

It was synergetics, which has successfully gained the status of the general scientific paradigm since the 1960s, that made fundamental adjustments to such ideas. Theoretical and empirical studies in natural science carried out within the framework of synergetics have shown that there are bifurcation points. I illustrated this concept above (Figure 1) when I mentioned a stone, the fate of which (i.e., development trajectory) can be determined by a minor, local (i.e., random) event.

Thus, it was recognized that systems, both physical and social, can experience such short-term states in which the consequent regularity (i.e., choice of an attractor) is determined by random influence. This means that a human act, even the action of a single person, can affect the whole of a social system along with the outcome of its evolution, historical regularity. Synergetics not only recognized the presence of chance and the ability of people to think and act arbitrarily, but also admitted that chance (a human act) can significantly affect the choice of regularity sometimes—that is, in the right place at the right time. However, such a choice is only possible when there are several attractors, options for further development. In addition, bifurcation points are quite fleeting, as I have already mentioned.

Finally, the SOC theory has shown that some systems can be in a state similar to a bifurcation point extended in time for quite a long time (even from a historical point of view). In SOC systems, every accident can lead to an avalanche, every human act can have historical significance. Moreover, the SOC theory postulates that events of different scales are generated by the same micro-level processes. In social systems, therefore, interests, ideals, actions, and interactions of individuals form historical regularities that include both tremendous revolutions and slight

shifts. The SOC theory not only allows for the existence of chance and its ability to determine regularity at some rare moments, but also puts chance on par with regularity and recognizes the equality of regularity and chance, which continuously influence each other. Of course, not all systems operate in the SOC mode, but—as I have tried to express in this article—in social reality, such systems are much more common than it might seem.

Conclusion

The extension of the SOC theory to the domain of the social sciences and humanities returns to the research agenda the longstanding attempts to understand, at least partially, the place of man in society and the role of the individual in history.

We used an extensive set of case studies, theoretical studies regarding SOC in the domain of the social sciences, humanities to clarify three questions that I think are important in assessing the heuristic capabilities of the SOC theory, and its relationship to the problems mentioned.

At the moment, the results published in the scientific literature indicate that SOC is present in many social processes, modern and historical, and can impart these processes' counterintuitive qualities, including disproportionate causes and effects, cascades of cataclysms of different scales, unexpected bursts of activity, "causeless" revolutions, and so on. SOC is especially important for understanding systems in a borderline state—that is, between order and chaos or in a transitionary period. However, there is not yet the necessary amount of empirical data that unequivocally testify in favor of the assertion that SOC is a ubiquitous and integral property of social reality. This is the answer to the first question about the limitations of the SOC theory.

The second question required verification of the assertion that the SOC theory allegedly substantiates the fundamental unpredictability and inevitability of social catastrophes. Although the SOC theory states that it is impossible to predict the place and time of avalanches, i.e., major transformations, in critical systems accurately, it provides a convenient tool to identify avalanche-prone systems and periods. As for the inevitability of revolutionary upheavals, the SOC theory is not alone in this view. Furthermore, the theoretical inevitability of major events does not detract from the right and ability of people to influence their format and outcomes. It should be noted that the SOC theory makes it unnecessary to have a major, extraordinary factor to explain major events.

Finally, the third question concerned the contribution of the SOC theory to ideas about the relationship between chance and regularity, human will, and historical necessity. I have tried to show that the SOC theory is the next logical step in the evolution of interdisciplinary paradigms that has been going on for more than three hundred years. The SOC theory originally created as a mathematized concept of natural sciences essentially states that in some social systems for a rather long time, even by historical standards, human will, act, and opinion can have a fundamental impact on the development of the whole of a system.

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