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Society as a Self-Organized Critical System

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In this article we apply the theorem of self-organized criticality from complexity theory to explain social transformations. We show that modern society meets all criteria of a critical system: close couplings, permanent addition of energy and the ability to slowly disequilibrate. The explanatory power of this approach is outlined by discussing the outbreak of World War I. Finally, we present possible intervention strategies to prevent social systems from collapsing.

I Introduction

The statistical probability for certain social events or sequences of events to take place is extremely low. Nevertheless, these highly unlikely events do occur. Often we ask ourselves, how could something like this have ever happened? One example of such a case is that of a driver who did not fully understand the instructions of his passengers and got lost in Sarajevo on June 28th, 1914. In an attempt to find their way back, they ended up in a narrow passage with no way out. At the moment they stopped a man called Gavrilo Princip passed by. Coincidently, he was a member of the "Black Hand Guard" – a terrorist group – and he happened to have a gun with him. As soon as he realized who was in the car, he took his gun and shot the passengers – Franz Ferdinand, the archduke of the Austrian-Hungarian Empire, and his wife Sophie – dead. This unlikely series of events lead to the outbreak of World War I (see also Buchanan, 2001 for another reference to this example).

In sociology, for this kind of unexpected and improbable chain of events the term *unintended consequences* (Merton, 1936) or *transintentionality* is used (Greshoff, Kneer, & Schimank, 2003). Further, it is complexity theory that is often useful for the analysis of such phenomena (Axelrod, 1997; Axelrod & Cohen, 2000; Herbst, 2004; Mandelbrot & Hudson, 2004; Waldrop, 1993; Urry, 2003; referring exemplarily to terrorism see Knorr Cetina, 2005; Urry, 2002). In the following article we draw on a specific concept from complexity theory – self-organized criticality – and show its sociological utility. Self-organized criticality can be used to derive a holistic description of the present society. Firstly, we explain the meaning of self-organized criticality (II). Then we try to demonstrate that the present society fulfils the conditions for criticality, but also show the limitations of this approach (III). Further we argue that modern society is basically directed towards a state of self-organized

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criticality. This implies certain consequences (IV). At the end some possible intervention strategies are discussed (V).

It is important to stress that this contribution does not simply try to map mathematical equations onto social structures, as it is for example advocated by Müller-Benedickt (2000), but uses a linguistic-theoretical approach instead. In Müller-Benedickt's view the verification of self-organization within a concrete social phenomenon requires computer simulations. Even though we acknowledge the difficulties of linguistic-theoretical approaches to verify the existence of dynamics described in concepts such as threshold levels, bifurcations, boundaries, transitions from order to chaos or attractor ranges, we argue in support of their significant utility in this context. In our opinion avoiding simulation – for example for the calculation of quantitative boundaries of thresholds parameters – does not preclude successful *concept-transfer* (Schulz-Schaeffer, 2002) between disciplines. By taking a linguistic-qualitative approach one can identify structural similarities between phenomena located within different fields of study. Such similarities can then be used to apply insights from one field of study to another, at least in the form of strong metaphors. This analytical strategy may help to discover new perspectives. However, an *innovation guarantee* can not be ensured. Between these two opposing approaches – metaphors versus simulations – one can find other approaches, esoteric (e.g., Capra, 1975), but also theoretically innovative views (for example Luhmann's [1984] concept of autopoiesis).

II. Self-Organized Criticality

The term *self-organized criticality* stems from theoretical physics. It has been developed in the area of complex dynamic systems (Bak, Tang, & Wiesenfeld, 1987) and refers to a specific family of systems.[3] To illustrate its general idea one often refers to the visualization of a sand pile on which new sand grains are slowly sprinkled (Bak, 1996; Bak & Chen 1993). This is an open, non-balanced system where energy (trickling grains of sand) is constantly added. Some of these falling grains may cause "avalanches" while others may cause nothing at all. Thus, a dynamic process involving the entire sand pile can be triggered by a single grain. Two characteristics of such systems are of particular importance.

Firstly, critical systems are scale-invariant. Generally, this refers to the fact that objects or laws do not change when the scale is multiplied by a common factor. In the case of the sand pile, the avalanches look nearly the same no matter how closely one zooms into it. In fact, small and large avalanches operate with the same logic. Let us think of a well-defined area of the sand pile. When for some reasons an avalanche occurs in this area, this may cause surrounding areas to slip down as well. The same

3. Referring to society, some other ideas represented by self-organized criticality can be found earlier. For example in A. Stafford Beer's (1959) work on cybernetics and management or Pitrim A. Sorokin's (1970) work on social and cultural dynamics. Both emphasize the systemic nature of social complexity but do not mention this explicitly.

logic describes the dynamics within a specific area. An avalanche in one section of the area may cause other sections in this particular area to slip off. Mathematically, this characteristic arises when the frequency and the magnitude of an event follow a power-law relation. Here, there is no normal largeness.[4]

One implication of scale-invariance is particularly important for us: When the same process operates on objects of different magnitudes, the same cause can have major or minor effects. A single grain dropping on a pile of sand can cause a large or a small avalanche. Hence, forecasting is impossible, that is we can not say when an avalanche will occur, and even if we observe a starting avalanche we are not able to say how big it will be. If one imposes this principle on the social world one can say: If society is a critical system every action/communication could produce unintended large or small consequences, and predictions are nearly impossible.

Secondly, critical systems are self-organized. This means that they fall back into the state of criticality without external shocks. Every single grain ultimately finds a local resting place that does not disturb the others. One can say that the pile self-organizes and builds up an increasingly complex structure. At some point all non-disruptive locations that do not cause the collapse of the system are occupied. When this point is reached the system is over-critical. Therefore, this system tends to be situated "at the edge of chaos." In physics one speaks of a dynamic system that has a critical state as an *attractor*. If this also holds for the social world, our society tends towards critical states with large and/or small consequences. As was shown by our example at the outset, sometimes these consequences can be catastrophic.

Concededly, our society is not as simple as the sand pile visualization suggests. There are other complex processes at work. Most obviously, the social world does not fit the dimensional monism of sand. There is dimensional pluralism with different aspects of the social world being conditional on each other while in the sand pile visualization there is only sand. For example economic conditions might provide the requisite for the appearance of self-organized criticality in the political sphere. Such a concern, may also be brought forward to argue that scale-invariance of social events depends on these conditions. Another difference between the sand system and the social system is that the latter has a meta-system, meaning that it can learn and attempt to regain stability. However, the point we want to make is that non-linear dynamics needs to be considered in the social world. Furthermore, societal upheavals may not be triggered by exogenous events, but may be consequences of how our society operates. Therefore, even a simplistic model as the sand pile may help to find answers

4. One could argue that power-law relations just formulate something obvious. Of course a large avalanche is rarer than a small one (or scientific papers with a high impact are rarer than papers with a small impact). But a power-law demonstrates more than this (Ball, 2004, p. 243): It describes how the probability of an event to occur relates to its magnitude. Two consequences are important. Firstly, in power-law relations, events that have a large magnitude are more probable than by pure chance. And secondly there is no a priori explanation, why the probability of an event to occur decreases by a constant power as soon as the magnitude of the event is doubled. "The general message of a power law is indeed intuitively obvious; the precise mathematical relationship, however, is not at all inevitable" (Ball, p. 243).

to unsolved sociological puzzles, as we try to show with of the outbreak of World War I.

III. Social Conditions of Criticality

Before we characterize society as a self-organized critical system by using a simple analogy it is necessary to outline the conditions that lead to self-organized criticality. After that it is possible to assess whether or not society meets these criteria. In general there are three conditions for critical systems. They refer to (1) a dense network of interactions, (2) specific boundary conditions, and (3) attributes of the system's elements.

(1) The first condition for self-organized criticality is the existence of a dense network of interactions of the elements inside the system. This implies that the entities in the system interact a lot. It is also possible to say that the elements in the system are closely coupled. Another implication of this condition is that the behavior of elements is non-linear. Because of the interaction between elements, they can intensify, but also soften each others behavior. Therefore the overall system can exhibit sudden shifts: Its future state cannot be predicted accurately with traditional statistical techniques. Small causes can result in large consequences, but do not necessarily do so. A telling example is given by Perrow (1987, p. 72). Referring to a nuclear power plant he says that even the replacement of a light bulb is a dangerous business in such a complex system as it may cause a major break-down. This first condition already distinguishes between mere chance and *deterministic chaos* (see van der Heiden, 1996; Dangelmayr & Hettel 1997; Küppers, 1996), however, two more criteria have to be met before one can speak of a self-organized critical system.

(2) The second criterion that needs to be fulfilled is that there is a permanent addition of energy to the system. This may take place in an unconstrained way. In the example of the sand pile, energy is added by new grains falling on the pile. However, there are no restrictions where the grains may fall down. This prerequisite guarantees that the system does not reach a steady state as a result of a lack of activity.

(3) Thirdly, the elements in the system need to have certain attributes. The form as well as the configuration of the elements exerts an influence on the criticality-process. This gets clear, when one thinks of rice instead of sand grains falling on a pile. Rice is pastier than sand and gets super-critical at a much slower rate (Springer, 1996). An avalanche of rice is less likely to occur than an avalanche of sand. For self-criticality to occur, the elements need to enable the whole system to enter a state of disequilibrium. Furthermore, the state of disequilibrium should be approached slowly. When this is not the case, one would end up in constantly critical states.

These prerequisites give rise to the question of whether or not our society can be described as a self-organized critical system. Some previous research has attempted to apply this concept to the social world (see Buchanan, 2001; Brunk, 2002). However, this body of work is highly specific and only investigates organizations (Perrow, 1987; Crozier, 1971) or interactions between actors (Paris, 1998). The purpose of this paper

is to examine society in a wider context. Specifically, we want to know if there are macro-social fields / systems that exist at the edge of chaos.

Close Coupled Systems and Social Non-Linearities

We will not attempt to answer this question in an empirical fashion, but rather investigate whether or not sociological analysis of contemporary society (see for an overview Schimank & Volkmann, 2000; Volkmann & Schimank, 2002) identifies the distinctive features of criticality outlined above. In particular, we draw from the following systems-driven theories: Richard Münch's (1991, 1995) diagnosis of the *communication society* and Niklas Luhmann's (1986, 1997a) vision of a functionally differentiated society.[5]

From Richard Münch's communication society we can extract that social systems are closely coupled. To arrive at this position the *theorem of interpenetration* in Münch's work is crucial. Interpenetration means that trouble-free working systems are in permanent exchange relations. They penetrate each other by producing inputs and consuming outputs of other systems (Münch, 1991, p. 345). Of utter importance in these mutual exchanges are symbolic generalized media. They play a major role in the *communicative exploded world* (Kron, 2000). One can say that they act as carrier of energy between the social systems and therefore enable the systems to find a balance. And it is such a balance between the systems which is necessary for them to work trouble-free. Thus, close coupling and interaction of social systems are implicit when systems work trouble-free.

However, Münch's perspective only accounts for linear dynamics. This goes back to the origins of Münch's communication society. To a large extent, it builds upon the systems theory of Talcott Parsons' which in itself prefers an equilibrium model (see Schmid, 1998, p. 238). That is why from Münch's point of view it is difficult to see that interpenetrations not only produce order, but also criticality.

Referring to Niklas Luhmann's (1997a) work in which he describes society as a *polycontextural* ensemble of autopoietic systems we can extend Münch and introduce non-linear effects.[6] Luhmann sees the society to be functionally differentiated. Further he says that society can be understood as a network of systems with a *high resonance factor* (1986). Once again, one can recognize the idea of close couplings. Social systems are somehow connected with each other. This becomes clear when we think of the idea of *exclusion interlinking* (Schimank, 2000b, p. 135). When a person is excluded from one system, this may result in the exclusion from other systems as well. For example, in some countries children cannot go to school when they do not have a permanent address. At the same time it may be very difficult to find a job when one

5. Sociological systems theory has a strong affinity to physics at the latest since Talcott Parsons who implemented cybernetic models of dynamic sampling and steering into his AGIL-scheme of social systems. Luhmann as well as Münch gave up this cybernetic orientation in their system theoretical variants. While Münch concentrates on cultural analysis, Luhmann adopts the idea of autopoiesis of Maturana & Varela from biology.
6. It is not the aim of this paper to identify specific forms of non-linearity, but rather to show that there is non-linearity. Similarly, we do not suggest that non-linearity always results in breakdowns or that the reason for a breakdown is always non-linearity.

has no education at all. With no job, one may not earn money and may not be able to afford medical treatment or legal protection and so on (see Luhmann, 1997a, p. 630). Luhmann has always emphasized that social systems are not autarchic, but only autonomous in the way they process data from the environment. Therefore, they can interact and irritate each other. Further, the binary codes and programs that are used by the systems are not exclusively defined by these systems alone. Instead they are structurally coupled, which means they depend on the circumstances. For example the economic system is able to define the criteria of how the love-code is used in the intimate system (Fuchs, 1999).

It is because of these interdependencies that Luhmann (1989, 1997b) was, for example, highly sceptical about political steering. In his view, changing one system may cause uncontrollable consequences in other systems. Additionally, the change in other systems may cause further change in the original system again and so on. In other words, the complexity of interactions of autopoietic operating and structurally coupled systems make collective events neither predictable nor controllable. We can take this as an indication for close coupled and non-linear interactions of social systems (Luhmann, 1997a, p. 763).

To summarize, even though Münch and Luhmann come to different conclusions they more or less agree on the fundamental tendency that social systems are closely coupled. When we leave Münch's criticized equilibrium model aside, we can extract from Luhmann that these systems interact in a non-linear way. From our point of view this general ascertainment of interaction complexity is in line with most other sociological theories, although one would need to specify it in certain aspects. For example, one can find close couplings in Bruno Latour's (1991) view of the increasing mechanization of society where hybrids represent a special form of close coupled interactions. Referring to the cultural aspect one can interpret Samuel P. Huntington's (1993) idea of the *clash of cultures* as an outcome of close couplings. Further hints on non-linearities can be found in Anthony Giddens' (1990) metaphor of the Dschagannath-wagon symbolizing the self-radicalization of the modern society. An indication for positive feedback-loops can also be found in the work of Jean Baudrillard (1978). Here, a feedback system of signs exists that evolves in a *hyper-reality* and which transforms the social world into a *simulation society*. When such feedback loops exist, non-linear interaction patterns are implicit. In another context Jürgen Habermas (1981) has shown, that non-linearities in the form of feedback loops cannot be stopped. In his thesis of a colonization of the life-world, he emphasizes that system-inherent imperatives, which directly refer to the absence of anti-deviance-devices, act in an uncontrollable fashion. Some more references to close couplings and non-linearities in the social world are found in *sociophysics*, where researchers try to understand the complexity of social life with the help of other concepts from physics (Ball, 2004; Buchanan, 2007).

IV. The Modern Society as a Self-Organized Critical System

As an intermediate result we can say that there are sufficient indications that contemporary society meets the first conditions of criticality. Now we argue further that the modern society is inherently designed to attract critical states. For this purpose, we make the argument that the natural development of society brings forward increasing cross-linkings and positive feedback loops. As Münch (1995) has said, the dialectic of the possible and the actuality (Münch, 1995) drives society towards rationalism, individualism, universalism, and interventionism. The fundamental direction of how society changes can be characterized by what Gerhard Schulze (2003, p. 81) has called the "game of increase." In this context, the society is transformed toward a *multi-option society* (Gross, 1994, 1999) where choice is a central element. Another consequence is that the modern society permanently needs to self-transform in an attempt to cope with self-created unintended consequences. That is what Ulrich Beck (1996) has in mind when he talks about *reflexive modernization*. The development of society is – as Beck puts it – not characterized by linear dynamics, but by "circular sum- and boomerang-effects" (Beck, 1996, p. 54) instead. The society needs to deal with unintended consequences of unintended consequences and so on. Therefore, modernization is followed by counter-modernization in a systematic way (Beck, 1996, p. 62). In a similar vein, one can interpret the arguments of Zygmunt Bauman (1992a, 1992b; Junge & Kron, 2002) who explains the Holocaust not as an "accident at work," but as an almost inevitable consequence of the modern pursuit of order. From our point of view, this systematic component in the development of society can be meaningfully described by the theorem of self-organized criticality. Every time the complexity of the social system is increased it comes closer to a critical state.

Ideas as Energy of Development

One source of energy in the development of the modern society is ideas.[7] By this we mean ideas about what is possible and ideas about how to make new options accessible. Without new ideas almost all dynamics in society would stop. A distinctive feature of ideas is that they enhance each other. Some ideas make other new ideas possible. An example is the idea to explore hereditary diseases. This has lead to idea of DNA-sequencing which in itself is the basis for the idea of (therapeutically) cloning. And it is foreseeable that this might just be the beginning for many more things to come.

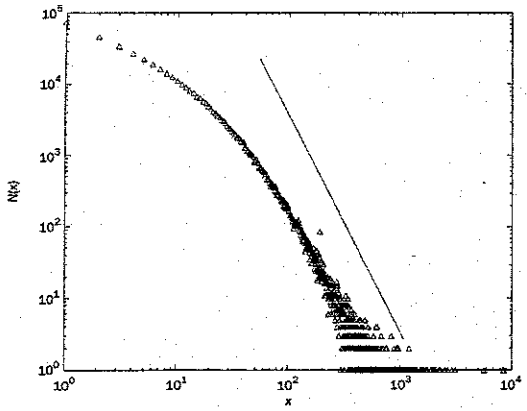
Ideas also possess a high degree of reflexivity. Today we have moved from the question of "How can we do it better?" to the question of "How can we think better to do it better?" Thus, most ideas also have a methodological component in it. In the context of DNA-sequencing it was not only the idea by itself, but also the methods and tools that were developed during the process that have further impact.

7. There are several other energy sources in social systems. How these energy sources interact and influence the different elements of the systems has to be investigated separately.

But reflexivity of ideas also means that some new ideas put some old ones in question (see for example Nagel, 1961). To elaborate more on this, let us think about the principles of how science produces knowledge. Scientific ideas are grouped and bundled together in scientific paradigms. Sometimes a new bundle of ideas comes up and the existing paradigm is put in question. This is what Thomas Kuhn (2003) labelled a *scientific revolution*. An example is the development of relativity theory in physics based on the work of Albert Einstein and others. It changed the whole understanding of classical mechanics, which was mainly built on the work of Isaac Newton. In the language of critical states, such paradigm shifts can be understood as "intellectual avalanches" within the scientific system.

At a first glance, it seems to be difficult to identify and measure these intellectual avalanches. However, Kuhn (2003, p. 11) gives us a solution for this. He proposes that we should look at the technical literature cited in the footnotes of research reports. Whenever a scientific revolution is going on, the old technical literature gets overthrown and new references become dominant. To get further insights, let us focus now on the distribution of scientific papers according to the number of times they are referenced in other papers. The following figure is taken from Buchanan (2001) and plots the number of scientific papers (x-axis) against the number of citations (y-axis). There are lots of papers with no or very little citations and only a few papers with many citations. Furthermore, we see a power-law distribution. When one doubles the number of citations, the number of papers falls off by about one eighth. Based on this power-law distribution, we can say that there is no true distinction between large and small scientific revolutions. The impact of a paper is scale-invariant. Thus, the ultimate consequence of an idea does not depend on its own inherent profundity, but on where it happens to fall within the network of scientific ideas.

Figure 1: Power-law of Science



Source: Buchanan (2001, p. 200)

Thus, science is probably a self-organized critical system that accumulates new conclusions until a paradigm shift occurs. When the complexity within an existing paradigm increases – because of new knowledge – the chances that additional discoveries will expose deficiencies of the paradigm itself are higher. Referring to the development of a paradigm, for example Midgley (2000) posits that it passes through a virtual stage in which it may either disappear or achieve a critical mass enabling it to be claimed as a paradigm. Furthermore, this provides an indication that there is permanent addition of energy to modern society.

To conclude, when society is a self-organized critical system, one should not only find breakdowns (paradigm shifts) in science, but also collapses in other social systems, for example, coups d'états in the political system, stock exchanges crashes in the economic system, reformations in the system of religion, or curricular reforms in the education system.[8]

Social Tension and the Latency of Criticality

But not all social systems exist at the edge of chaos! As already mentioned above, the model of physics that we use simply describes a general mechanism which still needs sociological specification. In particular, one needs to find out which kind of social structures and which kind of circumstances tend to get critical.

Most of the time criticality is a latent phenomenon and not visible. Therefore instead of only focusing on the critical state of collapsing systems, we can interpret the dynamics of criticality as some form of *macro-robustness* against additional energy. Not all acting of individuals causes a social avalanche. In these situations, criticality cannot be observed in a direct way, but indirectly via the degree of social tension in the social systems. From a sociological point of view we can define these tensions as interaction interferences which are the result of coordination problems, cooperation problems, or conflicts (Esser, 2000, p. 55; Schimank, 2000a, p. 173; Schmid, 1998, p. 150, 2004, p. 257). Each of these sources produces tension in a different way. In the coordination problem, actors have parallel interests and compete with each other. When there is a cooperation problem the participating actors have dominant rational strategies, but if all actors use this strategy the common utility is lower than it could be. When there is conflict, the interests of the actors are simply opposed to each other. Thus, we can identify different sorts of *social tensions* depending on how they were created.

However, as we outlined before, the general mechanism of self-organized criticality does not require any special kind of tension. Any form of tension can build up until the system reaches a critical state, regardless of whether it stems from a coordination problem, cooperation problem or from conflict. Therefore the behavior

8. Following a reviewer's comment, we want to emphasize that these discontinuities may be limited to a specific social system. For example a coup d'état is a political discontinuity in respect of political parties, but does not necessarily entail a discontinuity in the policies that emerge as well. However, these breakdowns may also stretch over different systems. An example is the takeover of the Taliban in Afghanistan in the 1990's which not only changed the political system, but also the economic system and the religious system.

of individual actors in a social system is of less importance than the topological-temporary relations. This becomes clear when we go back to the example of the sand pile. For an avalanche to occur, the form and shade of a single grain is less important than the position where the grain falls on the sand pile.

Based on this it would be wrong to conclude that the behavior of individuals is irrelevant. In fact, action is crucial when it takes place in certain environments. Without action no avalanches would occur at all. But at the same time, one cannot estimate social consequences from individual action alone. In a way this comes close to the idea of Georg Simmel (1992) who insisted to describe social tensions together with spatial-temporal relations as *Vergesellschaftungsformen.*

Another aspect is that social tension in a culture occurs through its internal dynamics of *immanent change* (see Sorokin, 1962). Consequently, the significance of discontinuities builds upon this and critical states might be reached at different points depending on the context. For example, the sexual freedom of a married politician would not be the same problem in France as in the United Kingdom. This example shows again that a simple analogy between society and a sand pile without sociological specification might be insufficient.

V. Endogenous End of the Modern Dynamics of Development

When one takes up the idea of our society being a self-organized critical system, one has to acknowledge that its development can result in total breakdowns. This stands in opposition to common evaluations. However, threshold values could exist, that need to be reached before social systems tend to collapse. In the case of ecological resources, Frederic Vester (1983) proposed that a total breakdown could be reached.

Another possibility for a total breakdown lies in the community system. Here, tensions in combination with a certain set of relations can result in "avalanches" that are wars. A total breakdown caused by a war is not completely impossible. Just recall the times of the "Cold War." The USA as well as the former Soviet Union had the means to destroy all human life on Earth.

Figure 2: Breakdown of a critical system

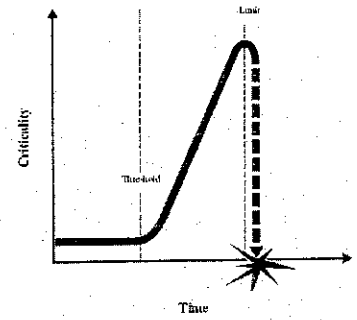
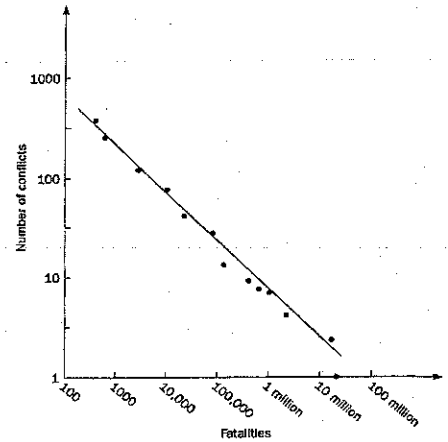


Figure 3: Power-law of War



Source: Buchanan (2001, p. 212)

Based on historical figures, when one plots the number of wars against the number of people killed in a war, once again there is a power-law relation (see Buchanan, 2001). This means again that there is no naturally small or large war. Given a specific configuration of social relations, a single cause can result in a total breakdown.

This opposes the views of other sociologists. For example Schulze (2003, p. 148) says that a breakdown is improbable because otherwise it would have already happened. Peter Gross (1994, p. 393) and Richard Münch (1995, p. 18) argue in a similar direction. They stress that the development of our society can only come to an end when the existing logic of development is substituted by another one. In contrast, the model of self-organized criticality shows that the development of modern society can come to an end simply because of itself.

To conclude, from our point of view, modern society can be seen as a self-organized critical system that endogenously reaches critical states. Small or large breakdowns can be caused by single events.

Once More: The Example of World War I

One could criticize the attempt to transfer the general idea of self-organized criticality from physics to the social world as being non-historical. In fact, some historians oppose the view that Germany somehow "slid" into war. A prominent representative of this view is the historian Fritz Fischer (1971) who argues that Germany has meticulously prepared the war since 1911. However, this argument is highly disputed. One could even speak of a conflict between historians. The antipodes to Fischer are the historians Gregor Schöllgen (2000) and Wolfgang J. Mommsen (1993, 1995) who emphasize the unintended consequences and interactions on the level of international

peace-keeping attempts as possible causes for the outbreak of World War I. In opposition to Fischer they argue that the international order was not only destabilized by the world-political activism of Germany and its military armament, but also by several peace-keeping activities. Based on this, it becomes hard to say that the outbreak of the war was simply an inevitable result of aggressive behavior.

Looking at this controversy in a neutral way, one sees that the arguments range between intended war, certain constellations of structures, and accident/primary-catastrophe. However, a model is missing that is able to bridge these ostensible inconsistencies. This includes an answer to the question what the general context was that made it possible for a relatively small event – the assassination in Sarajevo – to have dramatic consequences. In other words, we do not need an explanation for how the single historical event of the assassination resulted in World War I, but we need a macro-sociological explanation for the critical state that made such a series of events possible.

Applying the model of self-organized criticality, we can accommodate opposing views of historians in a single model. When we interpret World War I as a large avalanche, there was a long phase of latency. Even though the first half of the 19th Century was characterized by wars, there was no major conflict in the 43 years immediately preceding World War I (Förster, 2003). Close couplings and positive feedback loops between the nations were also very strong in that period. It was Otto von Bismarck who implemented a flexible system of alliances after the *unification wars* with Denmark, Austria, and France. All the great powers flinched from starting a war with each other despite of local hot spots and disagreements. When Bismarck was dismissed, Wilhelm II intervened and the secret Reinsurance Treaty between Germany and Russia from 1887 had been annulled, the tension within these interactions increased. The result was that the Bismarckian system of alliances was transformed into a set of even closer couplings dominated by two antagonistic power blocks. On the one side there was Germany, Italy, Austria-Hungary and on the other one side Russia, England, and France. When one looks at the series of cascade-like events that preceded the outbreak of the war one can see that these close-couplings produced positive feedback loops.

It is relatively easy to identify the pursuit of political power as the source of energy that pushed the overall system towards a critical state. There was the Tsarist Russian Empire that wanted to resume its old glory and power that had began to vanish after the unification of the German States in 1871. France followed a rather defensive foreign policy and simply wanted to avoid a German preemptive strike. This was a realistic and often emphasized threat. Another defensive player was England. Especially as some of the major goals of English foreign policy, for example the independence of Belgium, had already been attained in a diplomatic way. However, with the aspirations of the German Empire to become a hegemonic power, England retreated from its rather passive strategy and formed the *Entente Cordiale* with France in 1904 to oppose the Germans. Lastly, Germany was craving for more power and the enlargement of territories. This became very obvious at the latest in 1897 when

Bernhard von Bülow – the German Secretary of State – claimed a "place in the sun" for his country. His vision of Germany as a colonial power was the ideological foundation of German naval expansion, which began shortly thereafter. A result of this massive military armament was the beginning of an arms race.

The feedback loops embedded in such a constellation lead to the non-linearity of events preceding the outbreak of the war. But before we describe this any further, we explicitly point to some other events that had the potential to trigger a war, similar to the assassination in Sarajevo.

- Krüger's despatch in 1896, a congratulation telegram from Wilhelm II to the president of the Republic of South African where a British expedition corps had been smashed;
- the Huns-speech of Wilhelm II in 1900 that resulted in an international uproar. Before German troops left to fight in the Boxer rebellion in China, the German Emperor said that German soldiers would not make any prisoners, reminiscent of the Huns many centuries ago. He justified this policy with his idea that the Chinese should be reminded of German superiority.
- the bloody end of the insurgencies of the Maji-Maji and the Herero in 1904. Germany brutally subdued riots in its colonies.
- the "Daily Telegraph Affair" where Wilhelm II called the English "crazy like march-bunnies" in 1908;
- the Morocco-crises in 1905 and 1911, in which the Germans applied a gunboat policy and conspicuously displayed their military power (the so-called "Panther-jump to Agadir" in 1911, named after the gunboat *Panther*).

The question why these other events did not trigger World War I, but the assassination in Sarajevo did instead, has not been properly answered by historians yet. Furthermore, it remains unclear, why the extent of the war was not anticipated. In fact, the Germans only wanted to have a local war within the limits of the Balkans. This is what Bethmann Hollweg the German Chancellor at the time recommended to the German Emperor. Germany even actively tried to avoid a large-scale war. The logic was to give unconditional support to Austria-Hungary in their actions against Serbia in order to prevent Russia from backing up their Slavic neighbor. With the hope that Russia feared a conflict with Germany the *Triple Entente* (Russia, France and England) should have been blocked.

When modern historians speak about this as a fatal error in the assessment of the situation by the Germans, retrospectively this argument truly holds. However, one should also notice that the war in terms of its beginning, development and magnitude, was neither intended nor rationally planned. In fact, a large-scale war was never a seriously-considered option at the time. The model of self-organized criticality can be used to show how the permanent addition of energy (political power) to a close coupled system (of nations) can result in positive feedback loops. Doing so, we can explain how a single "historical grain of sand" (the assassination in Sarajevo) was able

to trigger an apocalyptic "avalanche of warlike actions" with more casualties than ever before. Some of the milestones of this self-amplifying process in the year 1914 were:

- July 23th: Even though it was not entirely clear whether or not Serbia was involved in the assassination plot, the Austrians sent a ten point ultimatum to the Serbian Government. They demanded amongst other things that all movements and organizations against their government be suppressed, the arrest and punishment of the assassins and their assistants and that all public criticism of their government be suppressed.
- July 25th: The Serbians were highly apologetic in their reply. They agreed to all the terms, but tried to explain that they could not control the freedom of speech of their people nor of their press. However, fearing the worst that Austria-Hungary would attack no matter of the reply, the Serbs mobilized their army anyway. All other nations thought that the Serbian reply would satisfy the Austrians, but three days later Austria-Hungary declared war on Serbia.
- July, 29th: After the Austrian attack on Serbia, it became clear that Russia would stand aside their Serbian friends, regardless of what the Germans would do. Noticing that, Germany made efforts to attenuate its unconditional support for Austria-Hungary. For example, the German Empire requested the Austrians to stop their attacks immediately after the conquest of Belgrade. However, as far as domestic policy was concerned, Germany could not back out so easily and kept on preparing for a possible war against France. The fact that on the one side Germany obviously tried to retreat, but on the other side did stop preparations for war shows that a process already had been kicked off that resembles an avalanche.
- July, 30th: The Russian Tsar ordered the total mobilization of the Russian army. The German public interpreted this as a highly aggressive act and began to think of Russia as the aggressor.
- August, 1st: Wilhelm II ordered the mobilization of the German armed forces as a heroic act to defend the fatherland. On the same day he declared war against France and started an invasion of Belgium.
- August, 4th: Germany let an ultimatum elapse that was set by Britain to retreat from Belgium. The result was that Britain declared war against Germany on the same day.
- August 6th: Wilhelm II said in his appeal to the German people: "In the midst of the peace the enemy attacks us. Go to the arms! Every hesitation would be a betrayal of the fatherland".

Until the final capitulation of Germany on November, 11th in 1918, over 60 million soldiers fought in the war on both sides, 10 millions of them died and 19 million were mutilated. We showed that the model of self-organized criticality can be used to describe the underlying dynamics of this escalation. A further sociological account of this process would need to discover the necessary and sufficient configurations of

conditions and to reconstruct the typical path dependencies of war dynamics (Mayntz, 2002a, 2002b). To provide a micro-foundation of war dynamics, further research would need to explain the decisions of typical actors (Kron, 2005a; Schmid, 2006).

VI. Conclusion

To summarize, we believe that there are sociological arguments which make it plausible to transfer the concept of self-organized criticality from physics to the social world. We referred to variants of sociological systems theory in order to show that society meets the criteria to be a critical system: 1) social systems are interweaved in a dense network of complex non-linear, mutual relations, 2) there is a permanent addition of social energy (for example ideas, power and so on), and 3) society is a system that – depending on specific kinds of social tensions – is able to slowly disequilibrate. Furthermore, we argued that modern society develops towards critical states. At least, it has been shown that the concept of self-organized criticality can contribute to find answers to open or disputed historical questions. This is exemplified in the case of the outbreak of World War I.

VII. At Last: What Can We Do?

Subsequent to the "diagnosis" of society as a self-organized critical system one can try to find a "therapy." When we have a model for escalation processes in the social world such as World War I, what can we do to prevent similar catastrophes from happening? We think that simply constraining social systems does not work. Instead we propose that one should try to prevent social systems from reaching their critical state. According to Haag (1996, p. 240) there are two general strategies which both draw from complexity theory: suppression of super-critical structures and selective targeted intervention.

Suppression of Super-Critical Structures by Frameworks

The historian Ludolf Herbst (2004), who tries to develop a theory of history based on chaos theory and complexity theory, advocates for the implementation of frameworks that are geared towards complex systems and do not refer to simple cause-effect chains. These frameworks should integrate positive as well as negative feedback loops into a system of counterweights to suppress super-critical structures. From this we can draw some parallels to Talcott Parsons' solution for the problem of social order. In Parsons' view normative frameworks are necessary to prevent deviation from the desirable. Following this line of thoughts we can interpret values as *deviance damping*. In this context, we do not define values as "conceptions of the desirable" (Kron, 2001, p. 198) but as conceptions of what ought to be refused instead .

Selective Targeted Intervention

The second possibility is selective targeted intervention. This becomes clear when we think of bifurcation points during the early development of systems (see Landfried, 1995, p. 262). It means that a short "kick" in a specific direction at the right moment can redirect the system's trajectory out of the chaotic area (see Haag, 1996, p. 242). Sociologically, this is not a task of anti-deviance devices concerning values but the concrete regulation of specific situations. In this context, Parsons emphasized the necessity of the institutionalization of values into the social system. There is a variety of empirical attempts that tried to do so, for example, the foundation of the Security Council of the United Nations as an anti-deviance device specifically dealing with armed conflicts. Another example is the attempt to limit population growth by actively integrating women in the labour force. These kinds of interventions do not conceptualize concrete goals and try to produce them. Instead they make use of self-producing mechanisms in the framework of abstract goals by excluding specific alternatives at the bifurcation points.

The Logic of Failure

The main difficulty in dealing with social complexity is to find appropriate frameworks or selective targeted interventions. Often, it is the inability of thinking in terms of dynamics, systems, and networks that leads to failure (Diamond, 2005; Dörner, 1996). Most individual actors have a limited focus (Dörner, 1996, p. 489). From their point of view, many events in everyday life seem to be independent from each other, do not have unintended consequences and are based on linearities and clearly identifiable causal relations. However, from an abstract social point of view this rarely holds true. Consequently, individual actors often make wrong assumptions about the future. Important parameters are left out of consideration, others are over-emphasized and extrapolations are based on linear trajectories.

When we take the notion of society as a complex critical system seriously, the most reasonable intervention strategy is one that is characterized by a series of small steps (see Popper, 2003, p. 59). Instead of fighting against windmills in the hope to change a system as a whole, it makes sense to use the power of system dynamics in a positive way (Vester, 1983, p. 117). On this note Robert Axelrod and Michael D. Cohen (2000) speak of harnessing complexity as an attempt to make positive use of complex dynamics in society, even though it seems impossible to keep total control.

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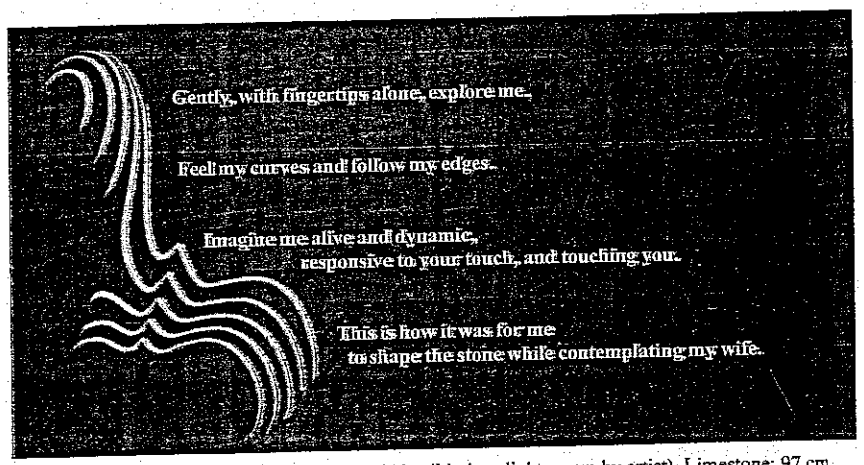

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