Chapter 2

Problem of contagion in complex systems*

Marcin Grabowski, Sławomir Wyciślak

Introduction

The premiere goal of the chapter is to identify basic premises and features of contagion in complex systems, focusing on multinational corporations. For this sake, methodology of contagion will be created based on both concepts of contagion itself, as well as system identification procedures and types of contagion. This chapter sets also methodological framework for future studies both in multinational corporates sector, wider real economy sector, and social systems in general.

The study is based on the thesis as follows: The scope and intensity of contagion effect in complex systems depends on the level of centralization of such systems.

The aforementioned hypothesis is analyzed based on following assumptions and deal with research problems outlined below:

- Having in mind the dynamics of contagion, the conditions in which self-organization is desirable, and conditions where centralization can be justified.
- The advantages and drawbacks of self-organization and centralization amidst contagion.
- The role of self-learning, and its impact on the ability to control and emerging patterns of behavior in the system.
- The inertia, reflexivity as components of self-organization and centralization within the complex systems.
- The concept of absorber within the self- organization process.

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The absorber is a category that describes the attraction of agents within the system. The absorber could be a leader, a value system that attracts agents amidst contagion. Learning contributes to alter strategies seeking absorbers.

As for the purpose of the study, the multinational corporation will be defined as a complex system to be analyzed.

2.1. About contagion

The concept of contagion was used by Ricardo who attributed the panic leading to the suspension of convertibility in 1797 to "the contagion of the unfounded fears of the timid part of the community" (Kelly & Gráda, 2000, p. 1110). In 1895, the French sociologist Le Bon wrote that ideas, emotions, opinions that fuel the crowd have the power of influence as germs (Le Bon, 1986). The term "contagion" was rarely used before 1995, after which it occasionally appeared in articles discussing the impact of the Mexican Peso crisis on other countries in Latin America. Use of the term was extremely limited. It was not until Thailand's 1997 devaluation affected other countries in Asia, and then Russia's 1998 devaluation affected global financial markets. These events prompted a series of academic papers in the early 2000's attempting to measure, understand, predict, and prevent international financial contagion (Forbes, 2012).

The review of literature allows us to distinguish two basic approaches to the understanding of the term "contagion." They involve the spread of financial crises and imitation of behaviour. As part of the interpretative framework of such phenomena is viral marketing (Stewart, Ewing, & Mather, 2009; Trusov, Bucklin, & Pauwels, 2009), purchasing decisions (Argo, Dahl, & Morales, 2008) or behaviour within the supply chain (McFarland, Bloodgood, & Payan, 2008), the concept of contagion is used in the context of imitating behaviour. The approach to financial markets focuses on the spreading of crises, negative shocks or disturbances (Edwards, 2000; Kaminsky, Reinhart, & Vegh, 2003; Rose & Spiegel, 2009; Forbes, 2012).

However, both cognitive perspectives are sometimes complementary, and e.g. the analyses describing the spread of financial crises take into consideration the imitation of behaviour typical of the "herd behaviour." An essential strand of analyses undertaken within the framework of contagion is that it intensifies the existing interdependence (Kaminsky et al., 2003; Markwat, Kole, & van Dijk, 2009). It is assumed that contagion is subject to escalation, which is why local disturbances may transform into regional or even global crises (Markwat et al., 2009). Contagion is also defined as the co-movement in excess of that implied by the factor model, i.e. above and beyond what can be explained by fundamentals taking into account their natural evolution over time (Bekaert, Ehrmann, Fratzscher, & Mehl, 2011).

The phenomenon of contagion is also characterised by the fact that the classical mechanism of spreading crises involves investors in a number of countries owning the same assets or applying the same cognitive mechanisms. The latter results in, for example, the panic effect and herd behaviour, which, in turn, facilitate the spread of contagion (Roubini & Mihm, 2011).

The essence of contagion comes down to its capacity to impose its influence mechanism on the affected entities. Within the temporal frame, contagion can be attributed two properties, namely immediacy and rapidity. Immediacy consists in the fact that as soon as the mechanism of influence starts to operate, contagion occurs. Rapidity is tantamount to the intensity of the phenomenon. Its scope may include such attributes of contagion as its high frequency, which refers to the escalation of connections as result of contagion, as well as its capacity to multiply by replication in numerous situations. In terms of contents, contagion is said to be characterised by the surprise effect.

2.2. Complexity

Complexity science has been developing especially since late 1920s, but became more visible in 1968 when von Bertalanffy published his famous book on general systems theory (however, one can also refer to his earlier works, dealing with the issue and starting in 1928). Complexity scientists seek and scrutinize patterns and tendencies in complex systems. For the last few decades this theory has been present also in social sciences (Mesjasz, 2010).

As for the moment, achievements earned within the system approach may be perceived as next steps in explanation of the phenomenon of complexity. Therefore, three stages of development of system theories may be identified. First wave, right after WWII, is connected with development of computers and application of feedback employing machines. Second phase is associated with development of cybernetics and system dynamics, and finally the third stage based on new understanding of equilibrium in discontinuation theories (Anderson, 1999).

General systems' theory, cybernetics, chaos theory, as well as catastrophe theory aim at explaining deterministic systems' behavior. There is a different model of adaptive complex systems explanation. Research in this area suggest, as emerging order stems from interactions at lower aggregation levels (Anderson, 1999). Adaptive complex systems can both affect its environment, and change their structure without external input.

Complexity theory is composed of the chaos theory, dissipative structures' theory, as well as complex adaptive systems theory. Whereas the chaos theory and the dissipative structures' theory focus on general model developing, adaptive complex systems' theory applies multi-agent approach (Burnes, 2004).

Table 2.1 *Systemic approaches*

Systemic approaches	Research area	Representatives
General systems theory	hierarchy, purposefulness, diversity, morphogenesis, stability, ultra-stability, emergence and evolution, entropy, inputs-outputs, equifinality	von Bertalanffy, Rapoport, Boulding, Klir, Pichler, Miller, Mesarovic, Takahara
Cybernetics	control, information, communication, autonomy, interdependence, cooperation, conflict, autopoiesis, self-organization, self-control, self-reference, self-transformation, complex dynamic systems	Wiener, Ashby, Pask, von Foerster, Zopf, Beer, Mc-Culloch
Dynamic systems	interactions simulation, feedback, role of delays, inventory and flows	Forrester, Meadows, Richardson
Non-linear dynamics theory	bifurcations, attractors, chaos, order	Mandelbrot, Prigogine
Systems' methodology	general system interventions, integrative system methodology	Churchman, Vester, Checkland, Ulrich, Jackson, Schwaninger, Gharajedaghi

Source: own elaboration based on: Schwaninger, 2006; François, 1999; Laszlo & Krippner, 1998.

The changing nature of socio-economic systems have resulted in increasing number, intensity, variability and dynamics of interrelationships within social systems, which, in turn, have led to increased degrees of complexity. This observation applies especially to dynamic complexity, i.e. the emergence of problem areas within which cause-effect relationships are subtle, and where the consequences of actions are not obvious within various timeframes. These include, for example, situations where the same action causes quite distinct short-term and long-term effects as well as different local and global impacts (Senge, 2000).

When discusing the concept of contagion, we are dealing with the classic problem related to epistemological complexity of social systems. In particular, their semiotic complexity results from our capacity to imbue every piece of information with a theoretically infinite array of meanings, whereas semantic complexity stems from the fact that interpersonal communication depends on language and culture, which are inherently ambiguous and subjective. This is reflected in the notion of linguistic uncertainty that consists in the fact that linguistic entities do not adopt numerical values, but are composed of words, sentences and expressions. For this reason, the scope of semantic fields of information is variable.

2.3. Methodology

Authors focus on developing an analytical model, starting from identification of complex systems, concluded with system analysis itself (Cempel, 2008; Skyttner, 2005). A classical procedure of system identification will be implemented, as described below (Figure 2.1).

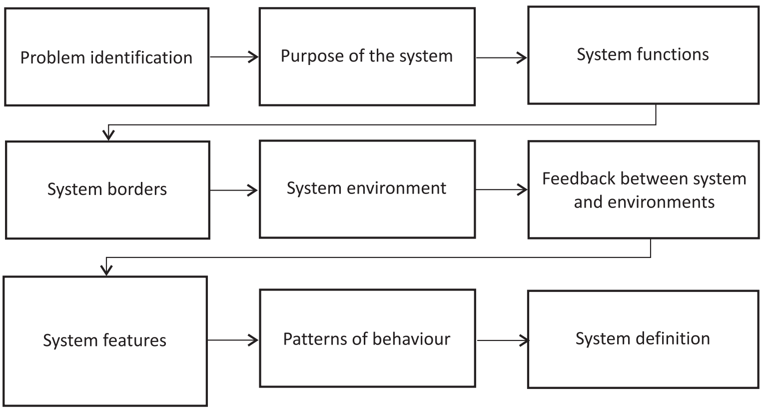

Figure 2.1. *System identification procedure.*

Source: based on Wyciślak, 2013, p. 117.

This will be followed by the procedure of analysis of the complex system in contagion, based on the initial model, shown below.

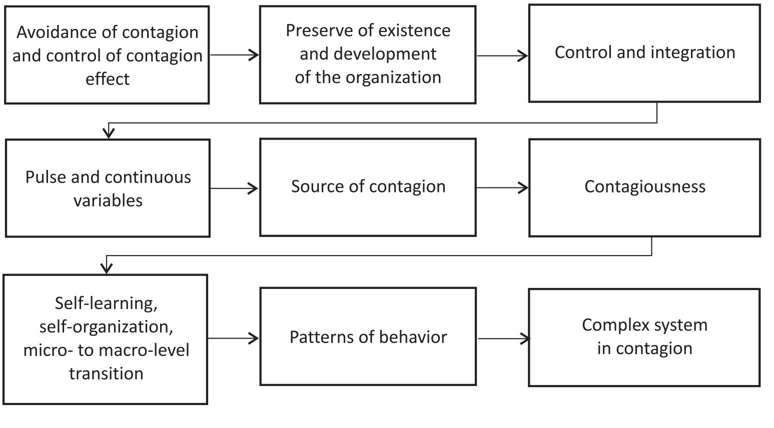

Figure 2.2. *Complex system in contagion.*

Source: based on Wyciślak, 2013, p. 51.

2.4. System identification

For analysis of contagion in the complex system it will be crucial to understand mechanism behind self-learning, self-organization, micro- to macro-level transition. This, in turn, will pave the way to construction of different patterns of behaviour within the system (Figure 2.3).

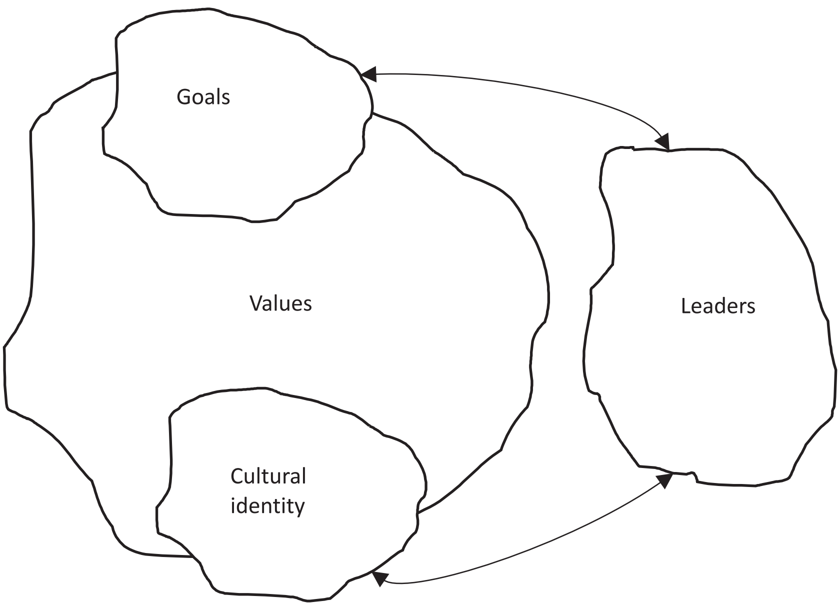

Figure 2.3. *Leading absorbers within the self-organization process.*

Leaders emerge in a variety of contexts and dimensions. Values, goals, leaders, cultural identity are interrelated and evolve. Subjectivity of agents provides a framework for the constitution of the absorbers. The subjectivity of agents is determined to the large degree by perpetration and reflexivity. At the same time, the level of awareness of agents is determined largely by reflexivity. Reflexivity of agent makes the tensions during the attraction. Tensions between absorbers and agents can be divided into substantive and emotional. On the other side, with the low levels of reflexivity, agents are inertial. By including reflexivity and inertia, we obtain various variants of modules constitution (Figure 2.4).

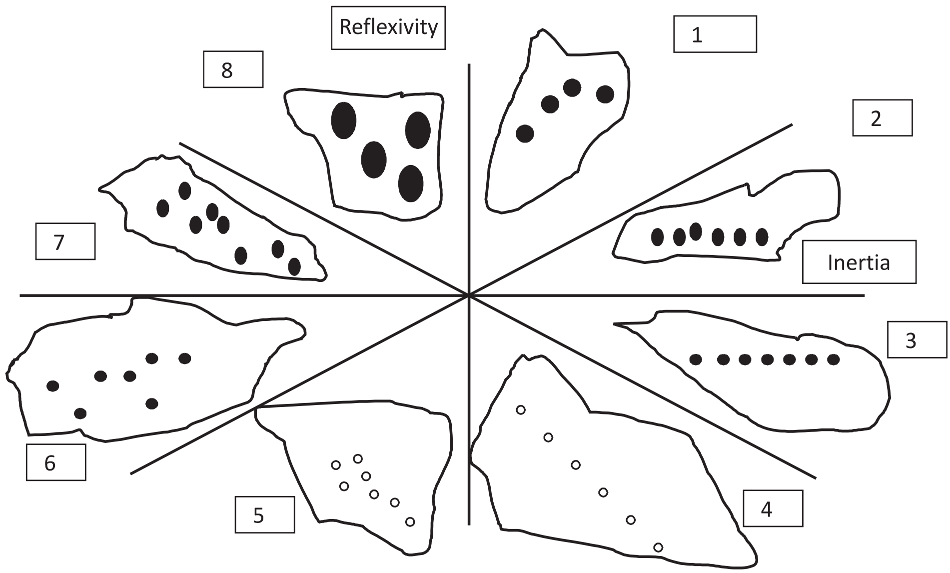

Figure 2.4. *Matrix of modules as effects of self-organizing.*

By high reflexivity level and relatively high inertia level, agents question leaders' rules, however due to the ad hoc needs for security they are on the trajectory dictated by the leader (1). By relatively high reflexivity level and high inertia level, the pattern of behavior follows the successive actions slightly deviating from the leader values (control norms) (2). By relatively low level of reflexivity and high level of inertia, we are dealing with an ordered set of actions (3). By low level of reflexivity and relatively high inertia level, there is an ordered set of actions of low level of consciousness (4). By low level of reflexivity level and relatively low level of inertia (5), there are actions that don't follow leader values (control norms), however they are of random, indeterminate character. By low level of inertia and relatively low level of reflexivity (6) there is an increasing number of activities of random character, not determined by leader. By low inertia level and relatively high reflexivity level, actions are increasingly conscious, which means an increase in potential of going beyond trajectory determined by values set by leader. By low inertia level and high reflexivity level (8) there is a set of activities of high degree of awareness, which define and implement own domain or in a conscious manner follow values set by the leader.

Researching reflexivity and inertia of agents will result in identification of emerging patterns of behavior. The role of reflexivity and inertia within the casual loops (feedbacks) between agents and absorber will allow us to answer how emerging patterns of behaviour evolve on the back of self-learning process.

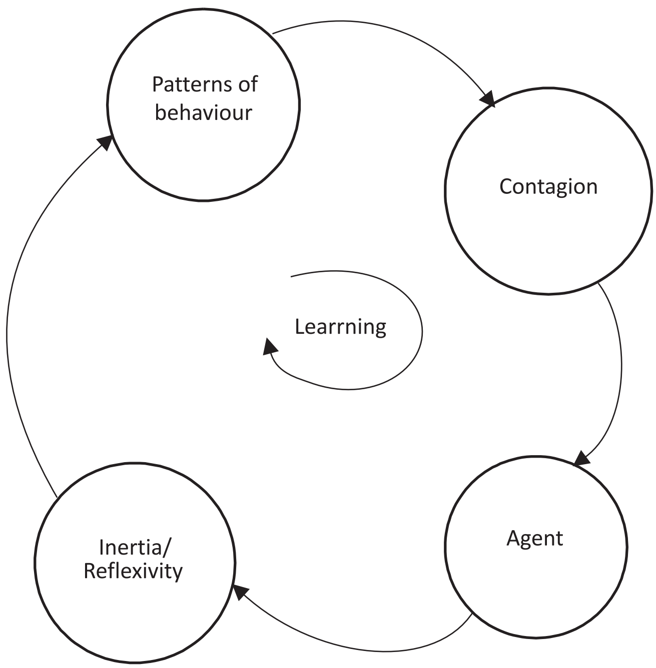

Figure 2.5. *Casual loops agents and absorber and self-learning process.*

Agents learn from the widespread of contagion effects and alter its attitudes (ratios of inertia and reflexivity), which in turn results in new patterns of behaviour. Emerging patterns of behaviour mean various levels of centralization in complex systems.

2.5. Centralization

From the system approach perspective, the centralization/decentralization problem is discussed by including optimization and suboptimization principles. When the whole system optimum prevails, not all subsystems are at their optima. As a result, it is hard to expect that the sum of subsystems' optima will necessarily lead to the total system's optimum. In other words, if the subsystems suboptmize but work towards the whole systems optimum, they will in aggregate reach a better total system optimum than if each tries to optimize its own system separately. The principle of suboptimization means that when the individual subsystems optimize its actions, the whole system doesn't work optimally. There is no contradiction in promoting on the hand, solutions worked out on a centralized basis, and on the other, implementation carried out by the decentralized decision units (van Gigch, 1991).

For example, in business practice, there are cases that the period after 27th day of the month sees 25–30% of the total monthly sales. It comes from the separate goals followed by subsystems including sales, marketing, finance, logistics. Whilst, the primary goal for the sales department is sales growth, the reduction of costs and fuelling the distribution centres and vehicles is the main goal for logistics.

2.6. Practical implementation

Based on Figure 2.1 (system identification procedure) we may briefly construct an analytical model for multinational corporation in contagion. There is a set of approaches towards the system itself, multinational corporation-centric approach will be taken into account in this paper. Therefore multinational corporation will be analyzed as a system. Problem identified here is naturally the contagion in complex system (being a multinational corporation), but at this stage the corporation itself, especially its structure is analyzed.

The purpose of the system in case of multinational corporations is bringing benefits for both shareholders and building fair relations with stakeholders. In case of shareholders, the research focuses mostly on financial benefits from stocks (increased value, often short-term and dividends). As for stakeholders it is more complicated. For one thing, the fair relations are hard to quantify, for another are of very high complexity levels.

As for system functions, components, interactions and structure, should provide profits/benefits for both shareholders and shareholders, but also preserve the system itself, providing its development. It means the ability to control and integrate internal activities.

System borders are marked with the legal structure of the corporation – we presume, legal entity, known as multinational corporation is a system to be analyzed. For this purpose the environment is multidimensional, including economic environment (financial, fiscal, monetary, etc.), social environment, as well as political environment. Feedback between system and environments is provided both by stakeholders, and it includes among others contracts, informal relations, and by set of incentives like regulations (from political environment), access to capital (from financial environment), etc. When it comes to contagiousness control, one of the key focus should be on protecting reputation for example as a reliable partner with which to trade.

Based on the aforementioned system features include self-learning mechanisms, self-learning, self-organization, micro- to macro-level transition.

The very core sense of systems features is micro – to macro transition. Resilience helps navigate the agents patterns of behavior. Equally, a resilient system is better able to translate the energy and engagement of its agent into immunity to contagion.

Patterns of behavior depend on system operation. There is a set of models of system operation, generally associated with models of multinationals centralization starting from centralized system (usually associated with multinationals, having headquarter in one country where the key decisions are taken and branches in other countries) to network structure (where hubs play the pivotal role, i.e. Logistics hub, R+D hub, the Operational hub, headquarter-hub). Multinationals only apparently follow the decentralization processes, by transforming themselves into network organizations. In reality, multinational corporations became integrators within value chains, and access to unique knowledge is the theirs' key competency.

Therefore, system, understood as a multinational corporation should be defined as set of elements, interactions and structures, separated from the environment (all what is not-the-given multinational corporation), however facing feedback from the environment because of stakeholders and regulations. System aims at providing highest possible profits for its shareholders and build fair relations with stakeholders, adjusting its patterns of behavior thanks to self-learning mechanisms.

Based and Figure 2.2 (complex system in contagion) we can refer to a set of events understood as contagion in a complex system of multinational corporation. Presuming the fact both system and the environment are in equilibrium, system of multinational corporation created set of mechanisms preventing from contagion and controlling contagion effects. In case of lack of the equilibrium our given system of multinational corporation tries to use this mechanism as the first step and primary defense mechanism. In case, it's impossible the next step is securing vital interests, hence existence and future development of the multinational corporation. For this sake mostly cost-reduction policy is applied, with different approaches, including reduction of non-profit operations, reduction of fixed costs, reduction of personnel, sale of lower-performing branches and outsourcing or outsourcing of certain processes. All of aforementioned aims at control and integration of company and contagion effect (including constant analysis of pulse or continuous variables). Source of contagion should be identified (either internal or external, it can affect all branches, all hubs, certain products, certain branches, the whole company). Based on those, we can assess the contagiousness of given operations/branches/products and react precisely where contagion effect is strongest. Self-learning mechanism supports multinationals in building better mechanisms supporting contagion-avoidance for the future, including proper patterns of behavior.

Discussion and conclusions

The final stage should answer, to what extend centralization (or central control) in complex system influence contagion effect and what is the role of self-learning mechanisms in preventing future crises.

Having in mind, both system identification procedure, but especially complex system in contagion and self-learning mechanisms, we may conclude as follows. If the multinational corporation system is decentralized, each branch can build its own model of prevention against contagion. However, it should be based on mechanism of self-similarity and redundancy.

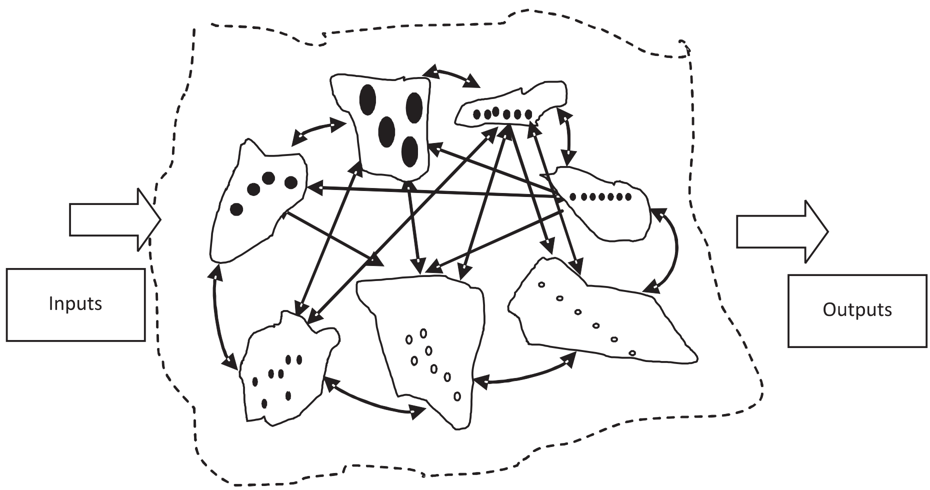

Figure 2.6. *Multinational corporation as a complex system (modules of various behavior patterns).*

In the case of global crisis, different branches are usually affected to different degree. In case of external source of contagion (like financial markets, limiting access to cheap credits), most branches may be affected. Such a global crisis is usually unlikely. In the second stage, however, certain local branch, can introduce self-organization, responding to the crisis and the model may be applied by other branches or each branch may create its own model (see Figure 2.4). Naturally, such a development requires relatively high level of reflexivity, hence at least operational level of management in a given branch.

In case of regional or given market crisis, this mechanism is even stronger. Hence, presuming each branch in decentralized structure may operate as an agent, possessing tools for high reflexivity, self-learning mechanism is faster and more efficient. Having this in mind, we may presume, decentralized system (as depicted in Figure 2.6) may react on inputs (bringing contagion) in a more efficient way than centralized system, with higher level of inertia. The best structure for the decentralized system, which is resistant to contagion, is fractal simultaneously cross-functional and has redundancies. The absorbers play the crucial role in ensuring and sustaining abovementioned structure.

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