A self-organization perspective of non-cooperative subject behavior leading to fatal shooting by law enforcement officers

[Till D. Frank]

Abstract—**Non-cooperative subject behavior leading to fatal shooting by law enforcement officers is discussed from the perspective of self-organizing systems. To this end, non-cooperative subject behavior is understood in terms of attentional blindness and functional fixedness as predicted by a mathematical model for self-organized human behavior proposed earlier by Frank (Nonlinear Dynamics, Psychology, and Life Sciences, 2015, 19, 111-146). Importantly, the same kind of model is applied to understand fatal shootings of non-cooperative subjects by law enforcement officers. It is argued and demonstrated by simulation studies that when the mechanism of fixedness acts both on subjects and law enforcement officers, tragic incidences of fatal shootings are likely to occur.** ***(Abstract)***

Keywords—**crimical psychology, non-cooperative behavior, fatal shooting, decision making, self-organization, determinism**

I. Introduction

Human behavior has recently been addressed from the perspective of self-organization [1,2]. The focus has been in particular on perception and coordinated motor control. The behavior of individuals or subjects confronted by the police, on the one hand, and the behavior of law enforcement officers, on the other hand, are particular instances of human behavior in situations that have the potential to escalate. In particular, the non-cooperative behavior of a subject may lead in the extreme case to the fatal shooting of the subject by law enforcement officers. While the self-organization perspective has successfully been applied to understand human perception and human motor behavior [1,2], researchers in this field of research have paid relative little attention to examine the aforementioned dyadic interaction between individuals and police. The objective of the present theoretical study is to understand the behavior of individuals confronted by police and the decision-making process of law enforcement officers to shoot down a subject from the perspective of self-organization. To this end, mathematical modeling in terms of amplitude equations will be used as motivated by synergetics [3] (a theory of self-organization and pattern formation founded by Professor Hermann Haken) and generalized variants of synergetics, namely, quasi-attractor theory [4] and extended synergetics [5,6,7,8,9,10].

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II. General considerations

A. Synergetics and self-organization

According to synergetics [2,3,4], self-organizing systems can be characterized by particular variables, called amplitude variables. The observed states of self-organizing systems may correspond to simple spatial patterns such as stripe patterns or simple temporal patterns such as oscillations. These patterns are associated with amplitudes. If the states under consideration are mutually exclusive, then a zero amplitude means the absence of a state, whereas a finite amplitude means that the pattern has emerged in the system of interest. Importantly, it can be shown that self-organizing systems under particular circumstances can completely be described by means of this kind of amplitudes [2,3,4]. Using a top-down modeling approach [11], it has been assumed that this approach also holds for self-organizing states whose precise description is more complicated. Human perception, action, and cognition has been addressed and mathematized using the amplitude equation approach [4,5,6,7,8,9,10,11]. For example, grasping a tool with one hand has been considered as a state associated with an amplitude. Grasping the same tool with two hands has been considered as a different state associated with a different amplitude [11]. Likewise, to decide (without performing any action) to grasp a tool with one hand or with two hands has been considered as two different psychological states associated with two amplitudes [9,10]. In both examples the states have been considered as mutually exclusive. Let us consider this scenarios featuring two alternatives in more detail. Let A_1 denote the amplitude of the first state and A_2 the amplitude of the second state. Then A1>0 and A2=0 means that the first state has emerged. Likewise, A1=0 and A2>0 means that the second state has emerged. According to synergetics, states emerge via bifurcations and evolve in time. Likewise, the amplitudes A1 and A2 have the tendency to converge to fixed point values. In fact, they do so, if all relevant internal and external parameters are held constant. The fundamental model that describes the evolution of the amplitudes A1 and A2 is given by [4,5,6,7,8,9,10,11]

$$\frac{d}{dt}A_k(t) = A_k(t)\left(\lambda_k - [A_k(t)]^2 - g[A_m(t)]^2\right) \qquad (1)$$

for k=1,2, where λ_k for k=1,2 are growth parameters. The parameter g is a coupling parameter and satisfies g>1. In what follows, we use the notation that the index “m” is the complement of the index “k”. That is, k=1 implies m=2 and vice versa k=2 implies m=1. For g>1 the model (1) is known to describe mutually exclusive states. That is, the amplitudes

A1 and A2 converge to A1>0 and A2=0 or to A1=0 and A2>0.

B. Amplitude equation modeling of functional fixedness

Functional fixedness refers to the observation that objects may have several functions. A simple box may be used as a container or alternatively as a platform to put something on top of it. A particular situation may require from an individual to perceive a particular function (e.g., the box as a platform). An individual may fail to do so because he or she may be fixated to the other function (the box as a container). If so, the individual is subjected to functional fixedness. In a more general sense fixedness can occur in situations that can be perceived in various ways. If a subject in such a situation, then the subject experience fixedness. An interpretation of fixedness with respect to the model (1) has been given in a previous study [7]. The model (1) is known to offer only a single long term solution A1>0 and A2=0 if the growth parameter λ1 dominates the growth parameter λ2. Likewise, the amplitude equation model (1) is known to offer only a single long term solution A1=0 and A2>0 if the growth parameter λ2 dominates the growth parameter λ1. The critical values can be determined analytically and are given by λ1/g>λ2 and λ2/g>λ1, respectively. If none of these two criteria are satisfied, then (1) offers both the long term solutions A1>0 and A2=0 and A1=0 and A2>0. Consequently, it is believed that the baseline condition of the perceptual system is such that neither of the two aforementioned criteria are satisfied. Functional fixedness occurs when due to certain circumstances such as priming the growth parameters λ1 and λ2 change such that one of the two criteria holds.

What we learn from these considerations is the following. Under baseline conditions, neither of the two criteria λ1/g>λ2 and λ2/g>λ1, hold. According to the model (1), in this case perception is bistable. In experiments involving the perception of object functions both object functions can be perceived. Likewise, when an individual is confronted with a particular scenario that offers two different interpretations, then both alternative interpretations can be perceived. However, there might be circumstances that affect the perceptual system such that λ1/g>λ2 or λ2/g>λ1 holds. Then the individual can perceive only one of the two possible object functions or can interpret the scenario at hand only in one particular way. The individual is subjected to fixedness. Note that functional fixedness is sometimes referred to as attentional blindness because we may say that the individual under consideration directs too much attention towards a particular interpretation of a given scenario. The individual becomes "blind" towards alternative interpretations.

III. Subject and police behavior

A. Non-cooperative subject behavior

Let us consider an individual confronted by law enforcement officers. In this situation the individual may be cooperative or may refuse to be cooperative. Let k=1 and k=2 refer to these two alternative subject behaviors. In line with our previous considerations on functional fixedness, we may assume that under baseline conditions the perceptual system of the individual is prepared in such a state that both possibilities (cooperation and non-cooperation) are available (neither λ1/g>λ2 nor λ2/g>λ1 holds). In this case, depending on the prior history [8,11] of the individual, the perceptual system will converge to a state with either A1>0 and A2=0 or A1=0 and A2>0. In the former case, the subject will cooperate with the police officer or officers. In the latter case, the subject will refuse to do so. If the subject happens to have criminal intentions or for other reasons, the perceptual system may be prepared such that λ2/g>λ1 holds. In this case, irrespective of the prior history of the individual, the perceptual system will converge to the state or A1=0 and A2>0 and the subject will refuse to cooperate. Finally, we may also consider the case in which the perceptual system satisfies λ1/g>λ2 such that we are dealing with a "law abiding individual". Irrespective of the prior history of the individual, the individual will cooperate with the police. Let us return to the second case of a non-cooperative individual and to the first case in which due to the prior history the individual refuses to cooperate. The law enforcement officer or officers in such a situation will try to convince the individual to cooperate. A successful intervention will affect the perceptual system parameters λ1 and λ2 such that eventually the parameters satisfy the inequality λ1/g>λ2. That is, assuming a time-independent coupling parameter *g*, then the interaction between subject and police will either result in an increase of λ1 or a decrease of λ2 or both. As soon as the inequality λ1/g>λ2 holds, the individual will have a unique perception of the situation: the individual will perceive the situation as a scenario in which he or she should cooperate.

B. Decision-making of law enforcement officers and (fatal) shooting

What happens if the police intervention turns out to be unsuccessful? Without loss of generality, let us assume that there are several law enforcement officers involved in the situation at hand. We may describe their behavior collectively by means of the model (1) again. We consider the extreme case in which a decision has to be made to shoot the non-cooperative subject or not. Let k=1 refer to "do not shoot" and k=2 to "shoot". In order to more quantitative, let us formulate explicitly the mathematical model equations. On the one hand, the subject behavior is considered as an emergent behavior of a self-organization system. On the other hand, the behavior of the law enforcement officers is considered as an emergent behavior of a self-organization system. Both self-organization systems are coupled and can be considered as a whole self-organization system. This system can be captured by four amplitude variables Ajk with j=1,2 and k=1,2. For j=1 we are dealing with the subject confronted by the police officers. For j=2 we are dealing with the law enforcement officers as a collective group. The model (1) then becomes

$$\frac{d}{dt} A_{j,k}(t) = A_{j.k}(t)\left(\lambda_{j,k} - [A_{j,k}(t)]^2 - g[A_{j,m}(t)]^2\right)$$

(2)

Let us consider a non-cooperative individual that is in the state A11=0 and A12>0 and has parameters λ12/g>λ11. The intervention with the police does not result in a change of the perceptual growth parameters as described in the previous section. The subject remains non-cooperative. Moreover, we may assume that the degree to which the subject is non-cooperative increases over time. For example, the subject may start to threaten the police officers. Accordingly, we assume that λ12 increases with time like

$$\frac{d}{dt}\lambda_{1,2}(t) = \alpha > 0 \qquad (3)$$

It can be shown that the increase of λ12 implies that the amplitude A12>0 increases with time as well [10], which reflects that the degree of non-cooperativeness increases over the course of time. We consider law enforcement officers who by default do not consider their environment as hostile and do not intend to shoot subjects that they confront. Accordingly, we assume that initially the perceptual growth parameters satisfy λ21/g>λ22. Irrespective of the prior history of the law enforcement officers, the "virtual" perceptual systems of the collective of officers will converge initially to A21>0 and A22=0. From the outside, we may say that the officers decide that the situation does not require shooting. As described above the officers will intervene and try to convince the subject to cooperate. However, the intervention is assumed to fail. The non-cooperative behavior of the subject will have two possible effect. The perceptual system may self-inhibit the "do not shoot" percept of the situation. Such self-inhibition of the "active" perception has been documented in several perceptual studies [5,6,8,9,10] and has been assumed to be the mechanism to overcome fixedness [7]. Mathematically speaking, λ21 is assumed to decay as long as the law enforcement officers perceive the situation as a situation in which they should not shoot. Note that this hypothesis is somewhat provocative. We will return to this issue in the discussion section. The decay of λ21 over time may change the relationship between the perceptual growth parameters such that eventually λ22/g>λ21 holds. At this point, the officers will decide to shoot the subject. Alternatively, or in addition to the self-inhibition mechanism, we may assume that there is a between person excitatory interaction such that the non-cooperative behavior of the subject will increase the growth parameter λ22 related to the behavior of shooting. Out of many possible mathematical models, we assume that the dynamics of λ21 and λ22 is given by

$$\frac{d}{dt}\lambda_{2,1}(t) = -\beta\,\lambda_{2,1}(t) \quad , \quad \frac{d}{dt}\lambda_{2,2}(t) = \gamma\, A_{1,2}(t) \qquad (4)$$

with β>0 and γ>0. Note that any other mathematical model would yield qualitatively the same results as those shown below. The increase of λ22 over time alone or in combination with the decrease of λ21 over time will result in a situation in which the perceptual is characterized by λ22/g>λ21. In this case, the system is monostable and as mentioned already above the decision is made to shoot the subject.

Figures 1 and 2 show a simulation of the model defined by (2), (3), and (4). Parameters are g=2, α=0.02, β=0.05, γ=0.9. Initial conditions are A11=0.2, A12=1.0, A21=1.9, A22=0.2, λ11=1.0, λ12=2.0, λ21=4.0, λ22=0.1. Parameter λ11 did not vary over time. The differential equations (2), (3), (4) were solved using an Euler forward scheme with single time step 0.01.

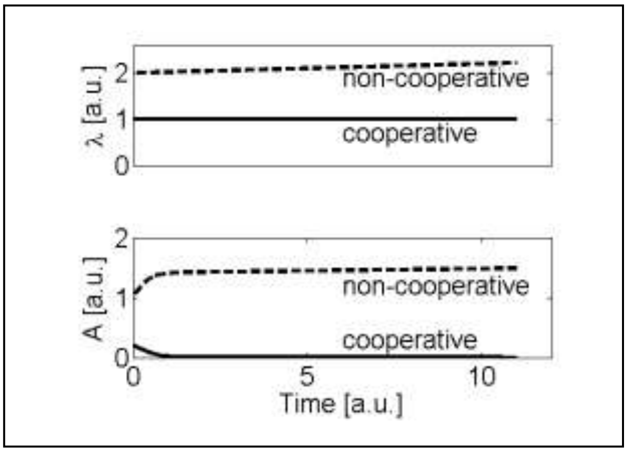

Figure 1. Growth parameters and amplitudes of the subject

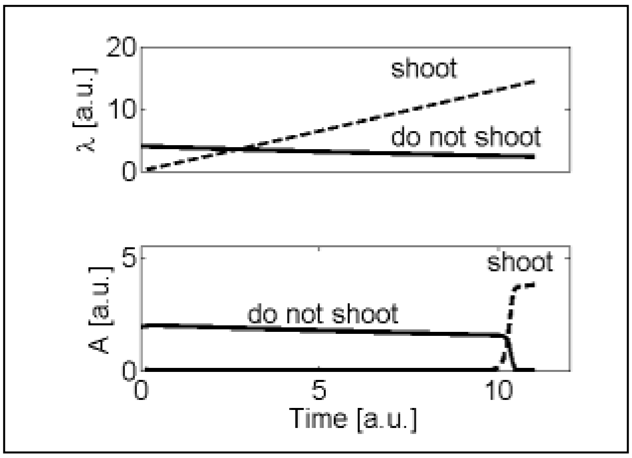

Figure 2: Growth parameters and amplitudes of police officers.

Fig. 1 shows λ11 (solid line) and λ12 (dashed line) in the top panel and A11 (solid line) and A12 (dashed line) in the bottom panel as functions of time. The growth parameter λ11 is constant, whereas λ12 increases over time, see (3). The amplitudes quickly converge to the state A11=0 and A12>0. The precise stationary value of A12 is determined by λ12 [10] and is given by the square root of λ12. Since λ12 increases over time, the stationary value of A12 increases as well. The individual becomes more non-cooperative. Fig. 2 shows λ21 (solid line) and λ22 (dashed line) in the top panel and A21 (solid line) and A22 (dashed line) in the bottom panel as functions of time. The growth parameter λ21 decays exponentially following (4). In contrast, λ22 increases over time, see again (4). The amplitudes initially converge to the state A21>0 and A22=0, where A21 is given by the square root of λ21. Since λ21 decays over time, the stationary value of A21 decays as well. As long as A21>0 and A22=0 the law enforcement officers maintain the decision not to shoot the subject. The decay of the amplitude A21 may interpreted that the degree to which the officers hold on this decision decays over time. At about 10 time units, the critical condition λ22/g=λ21 is reached. The perceptual system becomes monostable and there is a switch from A21>0 and A22=0 to A21=0 and A22>0. The police officers decide to shoot the subject. Alternatively, we may say that the law enforcement officers perceive or interpret the situation as a scenario that requires shooting the subject.

IV. General discussion and 4^{th} law

The behavior of subjects involved in a situation with law enforcement officers and the reaction of law enforcement officers to non-cooperative subject behavior has been discussed from the perspective of self-organization in general and within the framework of synergetics in particular. It was demonstrated that the so-called amplitude equation approach can be used to describe subjects that behave cooperatively or non-cooperatively towards the requests made by law enforcement officers. The same approach can be used to describe the decision making process of law enforcement officers involved in that situation.

Importantly, the approach can capture different types of interactions between police and individuals. The nature of these interactions is that the behavior as described by the amplitude variables affects the perceptual system as described by the growth rate parameters. The perceptual system in turn affects the behavior. Mathematically speaking there is a circular causality loop involving the amplitude variables and the growth rate parameters. System featuring this kind of feedback go beyond the classical systems addressed by synergetics and the theory of pattern formation. A generalized two-tiered theory of self-organization is required [4,5,6,7,8,9,10] in which one tier is given by the amplitude dynamics, whereas the other tier is given by the parameter dynamics. Such a two-tiered theory has been called quasi-attractor theory [4] or extended synergetics [5,6,10].

In section III.B we assumed that the decision not to make use of the option to shoot a non-cooperative subject is subjected to self-inhibition, see (4) for $\lambda 21$. As mentioned in section III.B we may drop this assumption. The between person excitation of the decision to shoot the participant as modelled by an increase of $\lambda 22$ when A12 is finite, see (4), is sufficient to induce a switch in the decision making process such that eventually law enforcement officers will decide to shoot a subject that over a long period of time is unwilling to cooperative. However, the self-inhibition hypothesis is appealing for two reasons. First, there is theoretical [4,5,6,7,8,9] and experimental [10] support for the self-inhibition hypothesis. Second, a decay of $\lambda 21$ implies that the amplitude A21 decays as well. The drop in A21 in turn may be interpreted that the non-cooperative behavior of the subject weakens the decision not to shoot the subjects. In line with this interpretation of the differential equation (4) for $\lambda 21$ does not primarily hold if $A21>0$ holds. Rather, the exponential decay of $\lambda 21$ holds as long as $A12>0$ holds. That is, the parameter dynamics describes a between person inhibition effect.

In closing this section, let us interpret the results obtained so far in the context of the so-called 4th law. The 4^{th} law states that transitions from one state to another (such as the decision to shoot a non-cooperative subject) go along with an increase in the rate of entropy production [12,13]. In order words, self-organizing systems exhibit a tendency to maximize entropy production (i.e., maximize the rate with which disorder is produced). In order to maximize entropy production, systems can change (make transitions) from one state to another. It has been argued that the principle of the 4^{th} law and the self-organization approach to understand human behavior and perception are related to each other. It has been shown that for certain classes of systems the growth parameters occurring in (1) correspond to measures of the rate of entropy production [6,14,15]. More explicitly, let us consider a neuropsychological interpretation of the amplitude equation model (1). Accordingly, we assume that the growth parameters reflect dendritic currents related to certain patterns of brain activity. In this case it has been shown that the rate of entropy production associated with a brain activity pattern k is a quadratic function of the growth parameter λk [15]. Let us consider the subject in the example discussed above. The growth parameters $\lambda 11$ and $\lambda 12$ are shown in Fig. 2. The corresponding entropy production rates are given by $c \cdot (\lambda 11)^2$ and $c \cdot (\lambda 12)^2$, where "c" is a positive constant. Fig. 3 (top panel) shows the corresponding rates for the non-cooperative and cooperative case. In our example, the subject is non-cooperative. The rate of entropy production related to the non-cooperative behavior is higher than the rate of entropy production of the cooperative behavior. Looking at the subject behavior from the perspective of the 4^{th} law, we may say the subject is non-cooperative because the non-cooperative behavior exhibits the higher rate of entropy production. Fig. 2 also shows the growth parameters $\lambda 21$ and $\lambda 22$ of the law enforcement officers. In order to keep with the aforementioned neurophysiological interpretation of the growth parameters, we assume that in the situation at hand there is only a single officer involved. The officer has to decide whether or not to shoot the non-cooperative subject. Using the expressions $c \cdot (\lambda 21)^2$ and $c \cdot (\lambda 22)^2$ we can compute the entropy production rates of the brain activity patterns associated with the two behaviors. The rates are shown in Fig. 3 (middle panel).

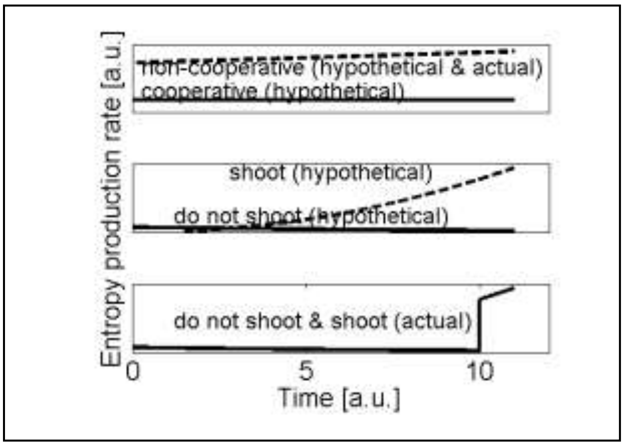

Figure 3: Entropy production rates. See text for details

The actually realized entropy production rates in the situation at hand are those related to the actually performed behavior. They are shown as a single graph in Fig. 3 (bottom panel). We see that when the officer decides to shoot the rate of entropy production jumps up as predicted by the 4^{th} law. Again, taking the perspective of the 4^{th} law, we may say that the decision to shoot the subject is made because the entropy production rate of the shooting behavior has become critically high relative to the entropy production rate of the alternative behavior.

These considerations about the 4th law add a novel point of view to the discussion about how to avoid (fatal) shooting. On the one hand, as mentioned above, a law enforcement officer would try to persuade a non-cooperative subject to give up his or her position and to cooperate. In order to do so, the police intervention should decrease $\lambda 12$ and/or increase $\lambda 11$. In terms of entropy production rates this means that the goal of the intervention would be to make the cooperative behavior to a brain activity state that has a sufficiently high rate of entropy production. On the other hand, shooting occurs when the growth parameter of the shooting behavior becomes high relative to all other growth parameters (in our example of only two parameters this means that $\lambda 22$ becomes critically high relative to $\lambda 21$). In general, we may subdivide the non-shooting behavior in various behaviors that do not involve shooting. To avoid shooting the law enforcement officer involved in the situation may be instructed or advised by his or her supervisor (if time permits) to attempt to resolve the problem by one of these alternative behaviors. This interaction would increase the corresponding growth parameter. From the perspective of the 4th law the goal of the interaction between the supervisor and the officer at the scene would be to increase the entropy production rates of appropriate alternative behaviors that do not involve shooting such that the officer would choose them rather than shoot the subject.

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