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Non-linear dynamics and leadership emergence

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Abstract

The process by which leaders emerge from leaderless groups is well-documented, but not nearly as well understood. This article describes how non-linear dynamical systems concepts of attractors, bifurcations, and self-organization culminate in a swallowtail catastrophe model for the leadership emergence process, and presents the experimental results that the model has produced thus far for creative problem solving, production, and coordination-intensive groups. Several control variables have been identified that vary in their function depending on what type of group is involved, e.g. creative problem solving, production, and coordination-intensive groups. The exposition includes the relevant statistical strategies that are based on non-linear regression along with some directions for new research questions that can be explored through this non-linear model.

Keywords: Leaderless group; Emergent leadership; Catastrophe model; Creative problem solving; Coordination; Self-organization

The emergence of leaders from leaderless groups is a well-documented phenomenon (e.g. Ansbacher, 1951; Bass, 1949, 1954; Cattell & Stice, 1954). Leaderless group exercises have become a staple in assessment centers for leadership identification. In the traditional research paradigm, group participants might be measured on a number of traits that could possibly be related to leadership behaviors. Members of the group then interact while carrying out a task. Then magic happens, and a leader emerges from the group at the end of the discussion period. The leaders are typically determined by a vote or by questionnaire items that have essentially the same purpose. Cattell & Stice (1954) found that not only did leaders emerge from leaderless discussion groups, but they also found two types of leaders: those who were regarded as the leaders overall by the group members and the technical leaders. Each type of leader displayed a distinctive set of personality traits. As expected, most group members were not identified as leaders.

The process of emergence remained a black box, however, until recently. The non-linear dynamical systems (NDS) concepts of self-organization (Bak, 1996; Haken, 1984; Holland, 1995; Kauffman, 1993, 1995), phase shifts, and catastrophe models for discontinuous changes in events (Thom, 1975; Zeeman, 1977) have unraveled the part of the process where the magic happens in leadership emergence and other social phenomena (Guastello, 1995a, 2002). This article recounts the recent theoretical and empirical studies that have resulted in a generalizable non-linear model for the emergence of leaders. The general model contains some variations depending on whether the group is involved in creative problem solving, production, or coordination-intensive tasks.

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1. NDS and catastrophe models for discontinuous change

NDS theory is not simply a group of methods for non-linear data analysis. It is a set of concepts that describe the various ways by which a system can change over time (Abraham & Shaw, 1992; Sprott, 2003). When NDS concepts are applied in psychology, the goal is to build a theory that elucidates how the dynamical concepts of changes in systems occur in a situation, and how psychological constructs are involved either as order parameters or control parameters.

Order parameters are essentially dependent measures in the social scientist's worldview. There may be more than one order parameter in some complex dynamical systems, however. Order parameters within a system might be completely independent of each other, or they might interact with each other as they evolve over time. *Control parameters* are essentially independent variables, with the important difference that they can act in ways that are more interesting than the simple additive relationships that are found in conventional research designs. Three distinct types of control parameters — asymmetry, bifurcation, and bias — are involved in leadership emergence dynamics, as described in a later section of this article.

The catastrophe models for discontinuous changes in events (Thom, 1975; Zeeman, 1977) involve combinations of attractors and bifurcations. An *attractor* is a stable state of behavior. Elements of a system (objects, people) gravitate toward these stable states and tend to remain there unless a powerful force is applied. A *bifurcation* is pattern of instability; in the cases considered here, the bifurcations involve the differentiation of a system into multiple stable and unstable states.

According to the classification theorem (Thom, 1975) given a maximum of four control parameters, all discontinuous changes of events can be modeled by one of seven elementary topological models (with qualifications). The models describe change between (or among) qualitatively distinct forms for behavior. The elementary catastrophe models are hierarchical and vary in the complexity of the behavior spectra they encompass. Change in behavior is described by differential equations that represent the structure of the behavior spectrum, or *response surface*. The cusp model that is shown in Fig. 1 is one of the simpler catastrophe models, and it is one that is most frequently used. The *cusp* response surface is 3-dimensional and describes changes between two stable states of behavior (attractors). The two attractors are separated by a bifurcation structure (manifold). The shaded region of the response surface represents a region where very few points, which represent behaviors (e.g. of people) within the system, are likely to fall.

Movement of points within the system around its response surface is governed by two control parameters. The asymmetry parameter governs how close the system is to discontinuous change in behavior. Imagine that the behavior of the system begins at the lower stable state of the response surface. If the asymmetry variable changes, no change in the behavior of the system is observed until a critical point is reached, where behavior changes suddenly. Behavior can change in the reverse direction, and again no change in the behavior of the system is observed while the asymmetry variable is changing until once again, a critical point is reached. Note that the critical points for moving in the "upward" direction are different from those associated with movement in the "downward" direction.

The bifurcation parameter governs how large the change will be. For large values of the bifurcation variable, change is discontinuous and rather dramatic as the system changes from one stable state to another. For low values of the

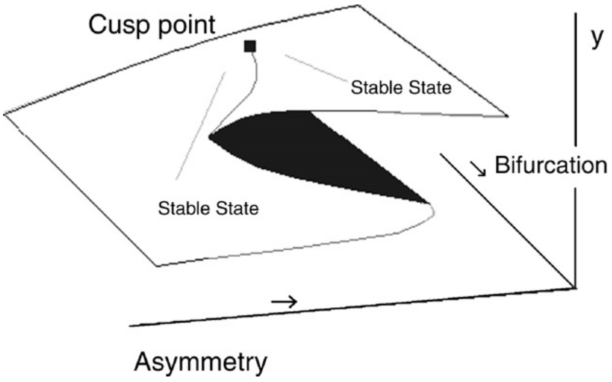

Fig. 1. The cusp catastrophe model.