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Do Emergent Leaders Experience Greater Workload? The Swallowtail Catastrophe Model and Changes in Leadership in an Emergency Response Simulation

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Although positions of greater responsibility imply greater workloads and consequences for actions, the experience of emergent leaders might be different. People who gravitate toward leadership roles might have a better understanding and skill set for the task requirements, and thus report lower workload. However, they might also report greater workload because they recognize demands that others do not foresee. Either way, the demands could impact a person's willingness to play a leadership role. This study examined workload effects within the framework of the swallowtail catastrophe model for leadership emergence. The experiment involved an emergency response simulation in two sessions; 348 undergraduates were organized into 44 teams of various sizes. Workload was experimentally varied by team size, number of attackers, and time pressure. Subjective experience was measured by standardized ratings of individual and group-level sources of workload. In the empirical models, team discussions contributed to the asymmetry parameter, group size contributed to the bifurcation parameter, and team performance corresponded to the bias parameter. Changes in leadership between sessions were explained by the same dynamics, but here, individual ratings of performance demands and frustration also contributed to the bias parameter; moreover, ratings of coordination demands—a type of group-level workload—contributed to the asymmetry parameter. Participants who were not leaders in the first session but assumed leadership roles later were less frustrated by the task, perceived the performance demands as greater, and perceived the coordination demands to be less compared to others.

Keywords: leadership emergence, cognitive workload, swallowtail catastrophe, NASA TLX, group workload

The work of managers and leaders has gradually changed since they were first articulated by Mintzberg (1973). One important change is the increased levels of workload among the incumbents (Tengblad, 2006). Although positions of greater responsibility require more mental, social, and other demands, leaders frequently delegate tasks to reduce their workloads. Alternatively, a micromanaging style could increase workload demands and possibly introduce side effects (Armstrong Persily, 2013; Hartley, 2012). The experience of would-be emergent leaders is not so obvious, however. Once involved in a group work situation, individuals have some opportunity to evaluate whether they want to take charge of the situation. The intrinsic value of the task, the ease of working with specific group members, whether anyone else in the group is trying to lead, and sources of workload from other parts of their jobs would affect the decision.

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As an example of the latter, Blackmore (2014) reported a general shortage of academics interested in administrative leadership positions. Although task knowledge could be a factor, the primary sources of resistance are the workload and temporal demands already associated with teaching, research, and production quotas.

Research addressing emergent leaders' perceptions of workload is sparse. Do leaders perceive higher workloads than their nonleader colleagues, and what are the contributing factors to their perceptions? Leadership emergence, meanwhile, is a nonlinear dynamic process in which the social structure of the entire group self-organizes and produces primary and secondary leaders as part of the process (Guastello, 2007a). The current study investigated these questions regarding workload and leadership using the swallowtail catastrophe model of leadership emergence. The swallowtail model is part of a broader perspective on leadership that engages principles of nonlinear dynamical systems (NDS) theory (Guastello & Gregson, 2011; Guastello, Koopmans, & Pincus, 2009; Sprott, 2003). Thus, the purpose of the present study is to examine how perceptions of workload affect the emergence of leaders in small groups.

The following sections of this article describe the swallowtail model and its known capabilities, the constructs of workload that are used in the ensuing experiment, and the experiment that involves teams engaged in an emergency response (ER) simulation. The exposition begins by identifying broad perspectives on leadership that are well-known, then contrasting them with the newer perspective from NDS theory. The latter addresses the importance of temporal dynamics in group experience. The swallowtail catastrophe model defines in further detail how discontinuities in leadership role structures emerge from a newly formed group and how workload and other variables—notably group size, team performance, and type of participation in the problem-solving discussions—play roles as control parameters in the process. The experimental design allowed not only an assessment of how leaders emerge, but also how groups could change leaders over time.

Leadership Emergence

Integrating Perspectives

In groups that do not have an explicit leader prior to the onset of a group task, primary and secondary leaders typically emerge given enough time (Bass, 1949, 1954; Cattell & Stice, 1954; Zaccaro, 2007). The primary leader probably exhibits a broad range of leadership acts and traits. Secondary leaders could be technical leaders, or they could contribute to other more specific roles and types of influences within the group. The traditional paradigm of leadership emergence research measures variables of interest (e.g., personality, situational influences) at the outset of the group activities and observes the leadership outcomes later. The process transpiring in between the two end points that produces the leadership roles received little attention until the introduction of the NDS paradigm.

Historically, academic leadership studies exhibited a sharp distinction between approaches that centered on traits and behavioral characteristics of leaders (Zaccaro, 2007) and those that instead centered on features of the leadership situation (Vroom & Jago, 2007). From the trait-based perspective, people who emerge as leaders in one type of situation can also lead in other circumstances where task demands are highly discrepant (Zaccaro, 2007). Thus, successful individuals in leadership roles are those who exhibit a broad repertoire of social, intellectual, and managerial capabilities (Guastello, 2007a, 2007b). The same broad repertoire of traits predicts success for leadership in a variety of task types.

The present study was not concerned with long-term characteristics in the sense of personality traits. Rather, the foci were the contributions to the problem-solving discussions that could be reasonably interpreted as resulting from such traits (Zaccaro, 2007). These leadership contributions included some that could apply to most any problem solving discussion (Benne & Sheats, 1948), some that were specific to creative problem solving (Guastello, 1995), and some that were specific to the ER simulation (Guastello, 2010a, 2010b; Guastello & Bond, 2004). The strategy behind this approach is revisited in the discussion section of this article.

Researchers have started to explore the development of secondary leaders from the vantage point of shared leadership. Shared leadership appears to engage the potential diversity within the group with regard to contributions an individual has to offer in either task-oriented or relationship-oriented domains (Fransen, Delvaux, Mesquita, & van Puyenbroeck, 2018). Fransen et al. studied newly formed groups over 24 weeks. The groups started as vertically structured with a leader in charge. As groups matured, the better performing groups were those that displayed increased average levels of leadership.

The situational perspective, in contrast, recognizes that particular leaders emerge in a given situation depending on the task complexity, information requirements, performance verifiability (Fiedler, 1964; Hirokawa, 1990; Vroom & Jago, 2007), and the group's preferences for dominant, considerate, or radical thinking on the part of their leaders (Bales, 1999), the group composition (Bell, Brown, Colaneri, & Outland, 2018), and who else appears to be taking a leadership role (Dal Forno & Merlone, 2006). The situational perspective also emphasizes versatility, flexibility, person–situation interaction dynamics, how the characteristics of a person might be shaped to environmental demands, and the individual's understanding of leader–follower interactions (Avolio, 2007; Graen & Uhl-Bien, 1995; Hackman & Wageman, 2007; Liden & Maslyn, 1998; Osborn, Hunt, & Jauch, 2002; Uhl-Bien, Marion, & McKelvey, 2007).

The NDS perspective on leadership theory shifts the focus from leadership as a noun to leading as a verb (Dooley, 2009; Hazy, Goldstein, & Lichtenstein, 2007). Ultimately, the spectrum of possible leader–follower interactions is embedded in an organization that has a surrounding climate of leadership generated by other leaders, organizational strategies, and individual jobs. Thus, leadership is a contextually driven construct that shifts depending on the temporal dynamics an organization is facing, for example, stability, crisis, dynamic equilibrium, or edge-of-chaos (Osborn et al., 2002). The far-from-equilibrium conditions that require quick adaptation are closer to the norm; a successful organization is functioning as a complex adaptive system where situation awareness, sense making processes, and creative thinking are critically important for the production of successful adaptive responses (Anderson, 1999; Dooley, 1997; Goldstein, 1994; Guastello, 2002; Kilburg & Donohue, 2011; Uhl-Bien et al., 2007).

Situation awareness and sense making are two cognitive processes that are intrinsic to ER. *Situation awareness* occurs when the individual has an accurate and sufficiently complete mental model of the situation, the available actions, and probable outcomes of those actions (Endsley, 1995, 2015). *Distributed self-awareness* describes an analogous cognitive state, particularly when the situation itself is constantly in flux (Chiappe, Strybel, & Vu, 2015; Fleştea, Fodor, Curşeu, & Miclea, 2017). *Sense making* describes the discussion and information sharing processes that ER groups use to translate raw situation information into an evolving action plan (Baber & McMaster, 2016; Weick, 2005). The problem situation can change rapidly, even chaotically. Thus ER teams experience social dynamics within their groups alongside other dynamics in the situation they are trying to resolve. The mainstay of the NDS perspective on leadership and organizational behavior addresses the deportment of leaders working in high-entropy, far-from-equilibrium, or chaotic environments. The topic now turns to the more focused case of leaders emerging from a newly formed group.

Emergence

The principle of emergence was introduced to sociology at the turn of the 20th century by Durkheim, who wanted to identify and study principles of sociology that could not be reduced to the psychology of individuals (Sawyer, 2005). In the general theory of emergence (Sawyer, 2005), myriad interactions among team members, task types, and environmental conditions eventually form patterns. The patterns persist and shape new interactions among other agents and continue to persist after the original agents are no longer available. Emergence is essentially a self-organization process, although some writers contend that emergence and self-organization are not unilaterally reducible to one another (Goldstein, 2011).

The emergence process just described is implicit in the leader–member exchange (LMX;

Graen & Uhl-Bien, 1995) and transformational leadership (Bass, 1985; Bass & Avolio, 1994) theories, which serve as illustrative examples here. In LMX, the building block of leadership is the quality of the social exchange and reciprocity among all group members. High-quality interactions are characterized by loyalty, respect, contribution, and positive affect (Liden & Maslyn, 1998). They have been associated with individuals' work performance, job satisfaction, satisfaction with supervision, increased role clarity, reduced role conflict, and leader–member agreement (Gerstner & Day, 1997). In early stages of interaction, the participants are learning who the other participants are, forming expectations about them, and figuring out their own roles in the social situation (Balkwell, 1991). When enough interactions have occurred, some people would attract more interactions than others, thus producing leaders and other roles (Graen & Uhl-Bien, 1995). In other words, local interactions thus give rise to global phenomena. An entire social structure emerges which reflects the dominant patterns and the formation of primary and secondary leadership roles (Guastello, 2007a).

Transformational leadership theory was focused primarily on the transmission of creative ideas within an organization. Again, the emphasis was placed on dyadic relationships, the quality of the social exchange, and reciprocity. Salient characteristics of these interactions include intellectual contribution, consideration of individual differences, inspirational motivation, and influence as a role model (Bass, 1985; Bass & Avolio, 1994). The potential for emergence was captured in an integrative process model (Eberly, Johnson, Hernandez, & Avolio, 2013), which posited that the LMXs are not independent of each other. Rather, they often occur in cycles as situations arise, problems are solved, and the effects of the remedies take shape. Event cycles can occur simultaneously (or asynchronously) at different activity loci within the organization, and these event cycles could integrate further into more complex interaction patterns. Although LMX and transformational leadership theories were developed with an eye toward phenomena in relatively large organizations, the same principles apply to the relatively small groups under study here.

Self-Organization and the Rugged Landscape

Systems in a state of high entropy, or far-from-equilibrium conditions, will self-organize by adopting new structures that dissipate less energy (Haken, 1984; Prigogine & Stengers, 1984). Hierarchical structures often result from a self-organizing process. The restructuring process occurs without the intervention of "managers" or "leaders;" it can also occur in nonliving systems. Although one landmark theorist (Kauffman, 1993) has famously described self-organization processes as "order for free," others have noticed that order is not as free as it might appear because there is no guarantee that the order will be to anyone's advantage (Goldstein, 2011). Thus it behooves those who hope to be in charge of a situation to recognize the dynamics in play and shape the otherwise-natural process toward a desirable end.

There are several models of self-organizing processes; the rugged landscape or NK[C] model (Kauffman, 1993, 1995) is the most relevant to leadership emergence. In a prototype scenario, a group of agents, differing on many randomly distributed variables that are not yet relevant to their survival, lives together in an ecological niche. A significant change to the environment eventually occurs that requires all agents to leave the old niche to find new ones. Each agent now carries a set of traits (K) that can be utilized for survival in a new niche composed of numerous other agents (N). After exploring their landscape for niches that provide fitness for their survival, many agents will select niches that require only one or a few traits for survival, and progressively fewer agents will select niches that require more traits for survival. If the complexity of interactions within the niche (C) is large, the social interactions within the niche will make it difficult to join, exit, or advance within. As the $NK[C]$ dynamics occur, the agents (group members) self-organize into a complex exponential distribution such that there is a high density around $K = 1$, multiple modes of progressively smaller densities as K increases; the last mode at high-K is somewhat separated from the rest of the distribution (Kauffman, 1993, p. 130).

Kauffman's simulations were based on the spin-glass algorithm: The molecules of glass (e.g., window glass) differ from those of a crystal in that glass molecules have magnetic forces that point in different directions. When the molecules are subjected to high levels of interaction, they reorganize into subgroups within which the magnetic forces all point in the same direction. This principle has been used to simulate the formation of homogenous social structures (e.g., cliques) within larger heterogeneous social units (Trofimova & Mitin, 2002).

Figure 1 is a simplified example of an $NK[C]$ distribution. Primary leaders are the fewest because their niche requires the greatest number of traits to survive. Secondary leaders come next because they have many useful traits but not as many as the primary leaders. In this example, multiple modes for midrange values of K are lumped together into one mode. This constriction is not unexpected because of the relatively small size of typical experimental groups in comparison to the enormous number of agents represented in Kauffman's (1993) simulations. The remainder of the distribution contains a high-density mode at the left that is typical for low-K agents (Guastello, 1998).

Swallowtail Catastrophe Model

Many of the discontinuities that occur in self-organization processes are closely similar to the discontinuities described by catastrophe theory (Guastello, 2005). Catastrophe theory (Thom, 1975; Zeeman, 1977) has been widely useful for describing and predicting discontinuous events. Its central feature, which is supported by Thom's (1975) classification theorem, is a set of seven topological models, which vary in the numbers of stable states, unstable states, and control parameters that they contain. The configurations of stable and unstable states and numbers and types of control parameters represented in each of the seven models are essentially unbreakable sets; if the set of states is known or strongly implicated, the corresponding number and type of control parameters is also strongly implicated.

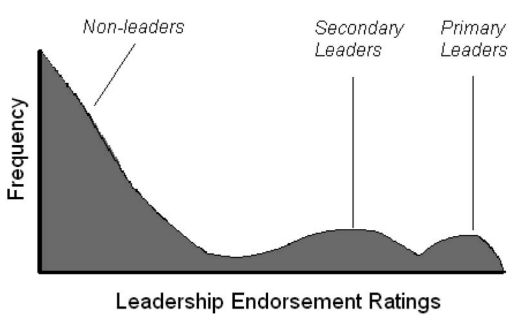

Figure 1. The swallowtail catastrophe distribution for leadership emergence.

The cusp model is the second-simplest catastrophe model and the one that has been adopted most often in psychological applications. The cusp features two stable states of behavior (formally known in NDS as *attractors*), a bifurcation structure between the stable states, and three control parameters. The swallowtail model has been applied only more rarely in psychology, the leadership emergence model being one of them, and work group performance over the course of a workweek being another (Guastello, 1985).

The swallowtail response surface (see Figure 2) is labeled for the hypotheses for leadership emergence in an ER game (Guastello, 2010b) and is defined as:

$$\mathrm{d}f(y)/dy = y^4 - cy - by - a \qquad (1)$$

where y is the dependent measure of interest that displays the discontinuous change; a, b, and c are control variables representing *asymmetry*, *bifurcation*, and *bias*, respectively (Thom, 1975); y in this instance is the extent to which a person is perceived as the leader of the group by other members of the group.

The swallowtail response surface is four-dimensional, so it is shown in two three-dimensional sections in Figure 2. The asymmetry parameter affords the movement along the surface from the left section, which is an unstable state, through a repellor zone (or *separatrix*) where very few points are expected to fall, to the right-hand section that contains two stable states. The two stable states have a separatrix between them as well. The bifurcation parameter moves points from the backside of the right-hand section up toward the front where the stable states (attractors) are located. The bias parameter produces the difference between the two modes. In applying the model to leadership emergence, the nonleaders, who would represent the bulk of the research sample, would correspond to the unstable mode at the left. The

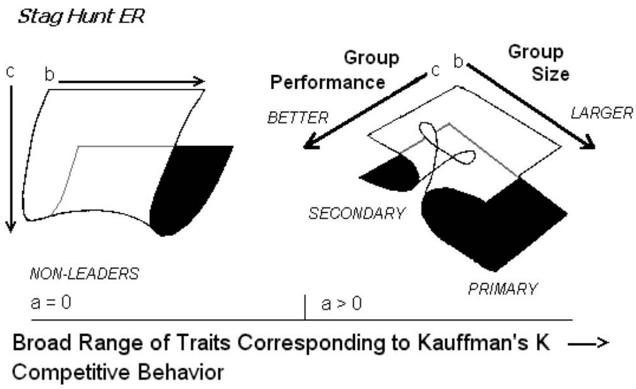

Figure 2. Swallowtail catastrophe model for leadership emergence in the ER task. From "Self-organization and leadership emergence in emergency response teams," by S. J. Guastello, 2010, *Nonlinear Dynamics, Psychology, and Life Sciences, 14,* pp. 179-204. Copyright 2010 by Society for Chaos Theory in Psychology & Life Sciences. Reprinted with permission.

primary and secondary leaders would appear within the two attractors at the right.

The swallowtail response surface can be tested by rendering the surface equation as a statistical model:

$$\Delta z = \beta_0 + \beta_1 z_1^4 + \beta_2 z_1^3 + \beta_3 c z_1^2 + \beta_4 b z_1 + \beta_5 a \quad (2)$$

where z is the behavior measured at two points in time (i.e., before and after a significant event that would induce a change in behavior; Guastello, 2013; Guastello & Gregson, 2011). The variable y (Equation 1) is transformed into z (Equation 2) with respect to location and scale. The transformation is also made on the hypothesized control variables a. The element $\beta_2 z_1^3$ helps fit the equation to the data if more points were changing upward than downward, or vice versa. When those imbalances do not exist, the term can be dropped from the statistical model.

Importantly, any integratable differential function can be represented by a unique probability density function (pdf; Cobb, 1978, 1981; Ito, 1951; Ozaki, 2012). Equation 2 is not viable for analyzing the emergence of leaders within one experimental session that has one set of leadership-related ratings at its end because the time-1 score is always 0.00 at the beginning of the work session. For this reason, the static probability density function (pdf) is used instead:

$$\text{pdf}(z) = \xi \exp\left[\theta_1 z^5 + \theta_2 z^4 + \theta_3 c z^3 + \theta_4 b z^2 + \theta_5 a z\right] \quad (3)$$

where pdf(z) is the cumulative probability of z within the distribution. ξ and θ_i are nonlinear regression weights. The argument to the exponent is an integration of the response surface equation (Guastello, 2013; Guastello & Gregson, 2011). $\theta_2 z^4$ is the optional element. Multiple research variables can be tested and included in either Equations 2 or 3 by expanding the terms containing a, b, and c into multiple addends, each with their own regression weight. The swallowtail pdf catastrophe function has been replicated several times in studies of leadership emergence (Guastello, 1998, 2010b, 2011; Guastello & Bond, 2007; Guastello, Craven, Zygowicz, & Bock, 2005; Zaror & Guastello, 2000), and a very similar distribution was identified in the dominance hierarchies of macaques (Flack, 2012).

To test for the swallowtail shape without yet considering the actual contributions of the hypothesized control variables, R^2 is determined for Equation 3 in which a constant of 1.0 are substituted for each of the control variables. Past results with the swallowtail model for leadership emergence produced R^2 values in excess of .90. When control variables were introduced the R^2 attenuated somewhat.

Once the swallowtail structure has been established, the simplest way to find the modes and antimodes is to evaluate unstandardized regression coefficients for Equation 4:

$$\mathrm{Freq}(y) = B_0 + B_1 y + B_2 y^2 + B_3 y^3 + B_4 y^4 + B_5 y^5 \quad (4)$$

and plot the points. This technique will be effective to the extent that enough points fall close to the attractors at the high-bifurcation side of the response surface. Otherwise, the modes will be less clear in appearance.

> *Hypothesis 1:* The distribution of leadership ratings given to of any one person by members of the group should exhibit a swallowtail distribution function.

Control Parameters

The broad spectrum. Next, we consider the psychological variables that function as control parameters and the rationale behind them. The swallowtail model requires three control parameters, which were defined in previous research (Guastello, 2010b, 2011; Guastello & Bond, 2007; Guastello et al., 2005) in terms of individuals' communication contributions (Bales, 1999; Benne & Sheats, 1948), task-specific contributions to the group discussion, and the experimental manipulations; see Table 1. The broad spectrum of leadership and communication behaviors usually made a strong contribution to the asymmetry parameter in the statistical analysis of the catastrophe model. When groups (engineering design teams) worked together over a period of several weeks as opposed to 2 hours in a laboratory experiment, the broad spectrum differentiated into two factors—one specific to facilitating and producing creative ideas and one containing most other aspects of the broad spectrum (Guastello, 2011); the creativity-specific variable contributed to the bias parameter instead.

Control variables in previous studies varied somewhat depending on the group task and the variables the experiments sought to explore at the time. The present study on leadership emergence was built on a previous one (Guastello, 2010b) involving the same ER simulation and in which the teams competed against only one attacker. The present study, however, expanded the experimental conditions to include one or two attackers and a second experimental session in which the participants returned for another set of simulations. Thus, Hypotheses 2–4 aim to replicate what was already known from the previous ER experiment. Hypotheses 5–7 examined the possible additional effects of workload.

> *Hypothesis 2:* A broad spectrum of contributions to the group discussions should contribute to the asymmetry parameter.

Group size. An optimal size for a group depends on the physical demands of the task, the types of mental or physical activity involved, and the amount of time available to perform the task. Problem-solving groups need to be large enough to produce a critical mass of ideas (Dennis & Valacich, 1993; Shepperd, 1993). Overly large groups, however, can be more prone to social loafing (Latané, Williams, & Harkins, 1979). The appearance of loafing

Table 1
Summary of Control Variables in Leadership Emergence Studies With the Swallowtail Model

Source	Task	Asymmetry	Bifurcation	Bias
Guastello, Craven, Zygowicz, & Bock, 2005	Creative problem solving	Broad spectrum: controlling the conversation, facilitating others	Creative contributions	(not found)
Guastello, 2011	Creative engineering design	Control of the discussion	Creative contributions	Facilitates creativity of others
Guastello et al., 2005	Production task	Tension reduction, goal realism	Creative control, production control, control of the conversation	(not found)
Guastello & Bond, 2007	Coordination-intensive	Broad spectrum: controlling the conversation, facilitating others	Verbal vs. non-verbal working conditions	Control of the task
Guastello, 2010b	Emergency response	Broad spectrum: competitive participation	Group size	Group performance

could result from poor coordination by the leader or team (Guastello, 2009). Typically, groups of three to eight members reach performance milestones more quickly than larger groups with nine or more members (Wheelan, 2009), but not always so (Guastello, 2010a). Because larger groups could have both benefits and liabilities, group size was tested as a bifurcation variable.

> *Hypothesis 3:* Group size should contribute to the bifurcation parameter.

Team performance. A common problem in executive leadership selection occurs when candidates for high-level positions often appear socially competent with strong track records of success in leading teams but struggle or fail once hired (Kaiser et al., 2008). Meanwhile, when a team succeeds, there appears to be a natural tendency on the part of outside observers to credit the leader, even when the critical work is produced by a self-directed team (Kilburg & Donohue, 2011). Leadership emergence research indicates that there is a bottom-up influence occurring as well. Primary leaders are more likely to emerge from groups that perform well (Guastello, 2010b). If teams have a performance goal that is not obtainable, however, primary leaders are less likely to emerge (Guastello et al., 2005). In other words, no one volunteers to be the leader of a losing cause.

Importantly, leadership theorists have begun to assess the roles played by followers in leadership-related events and the totality of the social structure in which they all reside (Eberly et al., 2013; Guastello, 2007b; Hackman & Wageman, 2007; Kilburg & Donohue, 2011). One might interpret the shared leadership phenomenon (Fransen et al., 2018) as a case of social structures evolving during that time, first by people moving to the right-hand side of the response surface in Figure 2, and then forward toward the secondary leadership attractor. Because the development of secondary leaders is partly responsible for better team performance in Fransen et al., we arrive at Hypothesis 4:

> *Hypothesis 4:* Group performance should contribute to the bias parameter.

Workload

Psychological studies in cognitive workload arose from the observation that there is a limit to the total quantity of information that a person or team can process within a fixed amount of time before error rates proliferate. Suboptimal but good enough decisions are generally the norm when complex decisions are required (Broadbent, 1958; Conrad, 1951; Guastello, Marra, Correro, Michels, & Schimmel, 2017; Rosser & Rosser, 2015; Simon, 1957). Importantly, there is growing evidence that people generally respond differently to workload stressors due to their differences in pertinent cognitive abilities, knowledge and experience, empathy and emotional intelligence, and flexibility in using coping strategies (Gruszka, Matthews, & Szymura, 2012; Guastello, 2014; Guastello et al., 2017; Guastello, Shircel, Malon, & Timm, 2015; Thompson, 2010).

The effects of workload on performance can be studied through performance differences that are produced by experimental manipulations, subjective ratings of workload, and physiological responses to workload. The former two approaches were adopted in the present study. Differences in workload that arise from various task conditions are not always apparent in task performance because individuals can employ coping strategies that buffer extreme workload levels (Hancock & Warm, 1989; Ralph, Gray, & Schoelles, 2010). As a result, subjective ratings of workload, such as the NASA Task Load Index (TLX; Hart & Staveland, 1988), have been valuable tools for research and system design evaluation. The TLX rating constructs are mental demands, physical demands, temporal demands, performance demands, effort required, and frustration. Although the TLX is responsive to differences in workload (Dey & Mann, 2010; Hart, 2006), a small amount of rating variance has been traced to personality traits and cognitive abilities that can limit the available mental resources devoted to the task or to adapting to changes in the task environment (Guastello et al., 2017; Guastello, Shircel, et al., 2015; Oron-Gilad, Szalma, Stafford, & Hancock, 2008). All other things being equal a task will be performed better if it is designed for lower workload on the TLX. As a caveat to this generalization, vigilance tasks are known for uncomfortably low levels of workload measured by other means but produce high ratings of workload on the TLX (Warm, Parasuraman, & Matthews, 2008).

The pervasiveness of teamwork in sociotechnical systems has generated new thinking that the group dynamics involved in teamwork add sources of workload in addition to individual workload constructs (Funke, Knott, Salas, Pavlas, & Strang, 2012). Thus, Helton, Funke, and Knott (2014) developed a set of subjective workload ratings for group workload (GWL)—coordination demand, communication demand, time sharing demand, team efficacy, team support, and team dissatisfaction—which were defined to parallel the TLX ratings. The GWL ratings are responsive to experimental manipulations of workload (Guastello & Marra, 2018; Guastello et al., 2017). The scales were negatively correlated with performance on a disaster prevention simulation (Helton et al., 2014).

Workload was manipulated in two ways in the present study: the number of attackers (monsters that the ER teams were required to defeat simultaneously as described in the Method section) and time pressure. The condition with two attackers was previously shown to produce higher ratings on both TLX and GWL ratings (Guastello & Marra, 2018) compared to one attacker. Hypothesis 5 followed from the results of an earlier leadership emergence study involving a production task in which the production quotas varied from feasible to unreasonably high (Guastello et al., 2005):

> *Hypothesis 5:* Task difficulty (number of attackers) should also contribute to the asymmetry parameter, which would distinguish nonleaders from either primary or secondary leaders.

What might be a difficult task for some team members might be more feasible for others. On the one hand, one might expect that leaders could report less workload from the task compared to others because of their intrinsic capabilities for the group task. On the other hand, leaders could be taking on greater levels of workload than others. Thus, it becomes an empirical question as to whether emerging leaders would report higher or lower levels of workload compared to other members of the group.

TLX ratings have been used as a single scale in much of the extant research, although it has been informative to treat them as separate scales in many cases (Sellers, Helton, Näswall, Funke, & Knott, 2014; Guastello, Reiter, et al., 2015; Guastello, Shircel, et al., 2015). The TLX performance scale sometimes behaves contrarily to the other ratings (Sellers et al., 2014). TLX ratings were treated separately in the present study.

TLX performance, effort, and frustration have previously contributed to the bifurcation parameter in some catastrophe models for cognitive workload and performance (Guastello et al., 2012; Guastello, Reiter, et al., 2015). In the leadership emergence context, they were once again thought to operate around the high-bifurcation portion of the response surface and because they could conceivably characterize an important difference between primary and secondary leaders.

> *Hypothesis 6:* TLX performance, effort, and frustration would contribute to the bias parameter.

GWL ratings, which only became available much more recently, were considered separately here as well. Because of their conceptual proximity to the broad spectrum of group discussion behaviors:

> *Hypothesis 7:* GWL ratings would contribute to the asymmetry parameter.

Punctuated Equilibrium and Time Pressure

Theoretically, groups change in their internal organization given enough time. As groups evolve, their members learn coordination and effective communication patterns simultaneously as they learn the demands of the task. In other words, there appear to be two learning curves transpiring at once (Guastello, 2009). Task learning is usually regarded as explicitly learned while team coordination and related group processes are implicitly learned. Furthermore, groups tend to undergo a qualitative and discontinuous shift, or *punctuated equilibrium*, in their internal dynamics approximately half way through their work time together (Gersick, 1988; Rebelo, Stamovlasis, Lourenço, Dimas, & Pinheiro, 2016). Although groups are expected to develop and mature over time, they do not necessarily display the same temporal patterns (Poole, 1981).

One could expect from the concept of punctuated equilibrium that ratings of GWL would decrease once the group automatized their perception-action sequences. Ideally, the group would strike a balance between maintaining a sufficiently complex repertoire of responses and adaptive capability while minimizing wasted energy; this balance is known as the *optimum variability principle* (Navarro & Rueff-Lopes, 2015; Schuldberg, 2015). On the other hand, the time pressure mounts for real-world groups while they are honing their internal process, which would imply increasing subjective workload.

Given that time pressures on experimental groups might not have the same realism as they would for real-world groups, we introduced a time pressure manipulation. The experiment involved two data collection sessions. A time-pressure instruction was given to some of the groups during the earlier session, and the instruction was not given to the others until the later session.

> *Hypothesis 8:* The swallowtail catastrophe model defined by Hypotheses 2–7 within sessions would also hold true for leadership changes across experimental sessions.

Methods

Participants

Participants were 348 undergraduate students enrolled in psychology courses at a university in the midwestern United States. Their ages ranged from 18 to 31 ($M = 19.04$, $SD = 1.32$). There were 102 males, 255 females, and three who did not report gender. The ethnic distribution was 254 White, 33 Hispanic Americans, 18 Asian Americans, 15 African Americans, 13 international students, 12 multiracial or other, and three who did not report ethnicity.

Participants attended three experimental sessions scheduled for 2 hours each. The first session required a full 2 hours. The second and third sessions required 1.5 to 2.0 hr each. Informed consent was obtained at the beginning of the first session, and the study was approved by the university's institutional review board.

The participants were organized into 43 ER teams of different sizes (five groups of three, 17 groups of four, one group of six, five groups of seven, 15 groups of eight members). The recruitment goal was to assemble four or eight participants for the ER teams (see experimental task description below), one or two to play the attackers (depending on the experimental condition), plus one more as an alternate to aid in minimizing the impact of attrition. Irregularities created by volunteers not showing up for the first session produced the group sizes of three, six, and seven.

Experimental Task

The experimental task was a board game entitled, *The Creature That Ate Sheboygan* (Guastello & Bond, 2004; Simulation Productions, Inc., 1979). The game was intended for two players, humans versus monster. It was modified so that the human player was actually a team. Monsters in the two-monster condition worked as a team against the ER team.

The ER team collected game points by depleting the monster(s) defense capability by utilizing military, police, helicopter, and firefighting forces. Monsters collected game points by burning buildings on the game board and decimating ER forces. A Godzilla-type monster was used in all experimental conditions. A flying Rodan-type monster, which had different movement and attack capabilities, was added to the two-monster condition.

The game terminated when the monster(s) collected a requisite number of points against the ER team, or the team collected the requisite number of points against the monster, whichever came first. In the two-monster condition, the team needed to collect requisite points against each monster before the game terminated. The instructions for gameplay, which were simplified from the original, appeared in Guastello and Marra (2018).

Other Procedures

In the first session, all participants completed three timed cognitive tests and an untimed survey that were not used in the present study; those data were used in other studies on workload topics (Guastello et al., 2017; Guastello, Correro, & Marra, 2018). The remainder of the session was spent learning the ER game. Sessions 2 and 3 produced two or three games for data collection. Participants were assigned roles as monsters or alternates by rolling a die; they maintained these roles throughout the series of games unless an alternate was needed to replace a participant that did not return to Session 3.

Otherwise, alternates helped the experimenters with counting game points.

Prior to the start of each game, ER teams had five minutes to position their tokens on the board while the monster(s) waited in another room. The monster(s) took the first turn. ER team members wore name tags identifying them by a number that corresponded to the response options on the leadership rating forms (see below). Participants provided ratings of individual workload and leadership at the conclusion of Sessions 2 and 3.

Of the 348 participants, 17 dropped out of the study after the first session and did not participate in the actual data collection. Of those remaining, 244 participated as emergency responders (ER) who competed against one or two monsters, 64 competed as monsters, and 22 were assigned as alternates; four of the latter replaced participants who dropped out of the study between Sessions 2 and 3.

Measurements

The experimental conditions consisted of group size, one or two monster opponents, and a 90-s time limit per move, which was introduced either at the start of either Session 2 or Session 3. Performance was assessed by the number of monsters killed within an experimental session, which usually consisted of three games. The two-monster condition without the time limit usually produced only two games. The possible number of monsters killed by the team ranged from 0 to 3 in the one-monster condition (actual range: 0–3) and 0 to 6 in the two-monster condition (actual range: 0–4).

Ratings for each of the TLX items were made by checking a box on a scale from 1 to 21. Hart and Staveland (1988) reported a test–retest reliability of .83 when the TLX was first published. Alpha reliability for the set of six ratings was .61 in Session 2 of the present study for ER team members only. We note that the ratings for performance demand was least correlated with the total score (r = .05). If this rating were deleted, alpha improved to .72. Alpha reliability for the six ratings was .64 in Session 3; if performance demand was deleted, alpha improved to .77. The correlation between the TLX total scores across the two sessions was .54 using all six ratings. The split-half reliability of .70 was obtained when the two sets of ratings were merged.

Ratings for each of the GWL items were also made by checking a box on a scale from 1–21. Reliability of the GWL was reported by Helton et al. (2014) as interclass correlations between items. The average value was .40 between subjects and .21 within subjects. Alpha reliability for the set of six ratings was .55 in Session 2 of the present study for ER team members only, and .61 in Session 3. The correlation between the GWL total scores across the two sessions was .53 using all six ratings. The split-half reliability of .69 was obtained when the two sets of ratings were merged.

Leadership ratings were obtained at the end of Sessions 2 and 3 after the workload ratings. The first item from the leadership questionnaire asked the participant to identify the person who was most like the leader of the group and the person who was second-most like the leader of the group. A team member was assigned 2 points for being most like the leader, and 1 point for being second-most like the leader. Raters also had the option of indicating that no one acted like the leader of the ER team. Monsters and alternates also rated the ER team members. Points were summed across all raters. Sums of leadership points were then divided by the number of contributing rating forms received to render a scale that ranged from 0 to 2. The same rating and scoring strategy was used for the next 18 items, which rated the ER team members' involvement with the group problem solving and their particular contributions to the problem solving conversation. Some items were adapted from Benne and Sheats (1948) and Guastello (1995), and some were task-specific. The same rating strategy was used for these items as for the leadership item.

Sixteen of the items were retained in the broad spectrum measure on the basis of a factor analysis. Those items were related to who asked the most questions; gave statements of fact; made clarifying statements; kept the group on-track (gatekeeping); initiated a problem-solving discussion; indicated a preference to a suggested solution; offered creative solutions; helped other members make timely plays; controlled the flow of discussion; controlled the moves of the army, police, helicopters, and firefighters; showed greatest concern for victory; competed to have their ideas tried first; and voiced the best strategies for killing the monster(s). Alpha reliability for the 16-item scale was .98 in Session 2 and .97 in Session 3.

Data Analyses

Data were analyzed in several steps. First, bivariate correlations were computed between the experimental conditions, broad spectrum, and workload ratings with leadership ratings as the criterion. This task served the purpose of identifying variables that had the greatest connection to leadership in simplest terms.

The second step assessed the swallowtail pdf (Equation 3 without the control variables) within each session using nonlinear regression. The error function was ordinary least squares. The initial values for the iterative process were set to 0.5 for all parameters. The parameter estimation procedure did not employ boundary values on any of the parameters. Location was the minimum value of leadership (y) in the distribution (0), and scale was its standard deviation, such that $z = y/SD$. The same corrections for location and scale were made throughout the catastrophe analyses that followed.

The third step evaluated the swallowtail model with the control variables included (Equation 3). Nonlinear regression was used once again with the same initial parameter values and no boundary values.

The fourth step computed linear models to compare against Equation 3. These were multiple regression models with leadership ratings as the dependent measure, control variables as the independent variables, and the backward elimination procedure. Linear comparison models would give indication as to how much information was added by using the nonlinear model. Linear models would be stronger than the nonlinear models if linear change was more pervasive than discontinuous change or if not enough time elapsed between the two observations (leadership ratings were hypothetically 0.00 for all participants at the start of each session) to allow a nonlinear process to occur. Linear models would also appear more accurate if they were capitalizing on a feature of the data that was also nonlinear but not adequately represented in the nonlinear model or otherwise controlled (Guastello & Gregson, 2011; Guastello & Mirabito, 2018).

The fifth step evaluated the swallowtail model for changes in leadership across sessions. The polynomial regression method (Equation 2) was used with the backward elimination procedure. Workload ratings from the end of Session 3 were used here.

The sixth step computed two linear models to compare against Equation 2. One predicted leadership in Session 3 from leadership in Session 2 plus the control variables. The other predicted change in leadership based on the control variables.

Results

Bivariate Correlation Analyses for Workload Items

Table 2 shows bivariate correlations between experimental conditions, composite variables from the leadership questionnaire, and ratings of individual and GWL with the leadership question (Q1). Leadership ratings were higher within groups that played against only one monster. These ratings were not affected by time constraint conditions or the performance criterion. There was a high correlation between leadership ratings and the broad spectrum factor. In

Table 2
Correlations Between Research Variables With the Leadership Question

Independent variable	Session 2	Session 3
Monsters killed	−.03	−.01
Number of monsters	$-.23^{***}$	$-.25^{***}$
Team size	.06	.00
Time condition	.01	.00
Broad spectrum factor	$.91^{***}$	$.90^{***}$
TLX mental demand	.05	−.03
TLX physical demand	−.00	−.04
TLX temporal demand	.12	.05
TLX performance	.06	.07
TLX effort	$.21^{**}$	.07
TLX frustration	$.21^{**}$	$.17^{*}$
GWL coordination demand	$.17^{*}$	−.02
GWL communication demand	.04	−.09
GWL time sharing demand	.10	−.04
GWL team efficacy	−.00	−.02
GWL team support	−.07	$-.17^{*}$
GWL team dissatisfaction	.10	−.02

Note. TLX = NASA Task Load Index; GWL = group workload.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

addition, we observed a moderate relationship between leadership ratings and efforts to support the group's morale. Individual effort, frustration, and ratings of coordination demand were higher among leaders in Session 2. These associations simplified in Session 3 to only contain a significant relationship between leadership ratings and frustration. Last, the need for team support was rated lower by leaders in Session 3.

Swallowtail Models Within Sessions

The structural models evaluating the degree of fit to the swallowtail's statistical distribution appear in Table 3. The data accurately resembled the swallowtail model's distribution. The structure was slightly better in Session 3 as indicated by the significant quintic term that did not occur in Session 2.

The high correlation between broad spectrum and the leadership question is partly the result of the two variables being swallowtail distributed (Guastello & Bond, 2007). The distributions of broad spectrum were also confirmed as being swallowtail-distributed here (see Table 3).

The control variables that corresponded to asymmetry, bifurcation, and bias in the earlier study with the Creature game, which were broad spectrum, ER team size, and monsters killed, respectively (Guastello, 2010b), were introduced next (see Table 4) as defined in Hypotheses 2–4. The number of monsters was also introduced as a second asymmetry variable (hypothesis 5). As expected, R^2 attenuated somewhat when all the control variables were entered. The model structure was once again stronger in Session 3 as indicated by statistical significance for all parameters.

The linear comparison models for these analyses are presented in Table 5. The R^2 values were higher than the swallowtail models due to the high correlation between Broad Spectrum and the leadership question. Of further interest, the swallowtail model captured a contribution for monsters killed that was not identifiable in the linear comparison models.

Workload ratings that were significantly associated with leadership in Table 2 were then introduced as additional control variables. They made no additional contribution to the accuracy of the swallowtail model when the model was evaluated within each session separately. Accordingly, they were not assessed in the linear comparison model.

Table 3
Nonlinear Regression Results for the Swallowtail Probability Density Functions

Model element	Parameter value			
	Leadership		Broad spectrum	
	Session 2	Session 3	Session 2	Session 3
ξ	65.512*	65.010*	1.000	11.753*
z^5	.002	−.011*	1.294*	.215*
z^4	−.038*	.038*	−15.225*	−2.753*
z^3	.159*	.052*	66.784*	13.407*
z^2	−.271*	−.303*	−134.728*	−31.266*
z	.353*	−.456*	124.885*	37.043*
R^2	.997	.998	.720	.998

* $p < .05$.

Table 4
Nonlinear Regression Results for the Swallowtail Models With Control Variables

Model element	Parameter value	
	Session 2	Session 3
ξ	54.443*	55.545*
z^5	−.028*	−.035*
z^3 × Monsters Killed	.224*	.269*
z^2 × Team Size	−.006	−.029*
z × Broad Spectrum	−.070*	−.113*
z × Number of Monsters	.021	.034*
R^2	.738	.741

* $p < .05$.

Table 5
Linear Comparison Models for Within-Session Dynamics

Variable	β	t
Session 2: R^2 = .822 (adj. R^2 = .819), $F(4, 208)$ = 240.592, $p < .001$		
Broad spectrum	.927	29.540***
Team size	.060	1.862†
Monsters killed	−.007	−.229
Number of Monsters	−.040	−1.300
Session 3: R^2 = .823 (adj. R^2 = .820), $F(4, 232)$ = 269.275, $p < .001$		
Broad spectrum	.939	21.174***
Team size	.088	2.938**
Monsters killed	−.004	−.137
Number of Monsters	−.055	−1.954†

† $p < .10$. ** $p < .01$. *** $p < .001$.

Table 6
Polynomial Regression for Critical Points

Model element	Session 2 *B*	Session 2 *t*	Session 3 *B*	Session 3 *t*
Leadership				
Constant	100.336	6.773***	76.200	6.686***
y	−414.732	−3.472*	−270.871	−2.933*
y^2	607.777	2.495*	381.133	2.034†
y^3	−296.256	−2.046†	−188.184	−1.676
y^5	22.584	1.620	15.005	1.399
R^2	.836		.825	
Broad spectrum				
Constant	75.918	8.803***	55.832	10.014***
y	−135.599	−5.205***	−80.810	−4.798***
y^2	87.598	3.987***	46.403	3.267**
y^3	−19.590	−3.374**	9.590	−2.555*
y^5	.313	2.702*	.136	1.820†
R^2	.824		.871	

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

The frequency distributions of leadership and broad spectrum were analyzed to identify modes and antimodes using Equation 4. Both variables were organized into 21 bins. Independent variables were entered simultaneously. The regression results are shown in Table 6. z^4 was not entered into the equation because its partial F to enter did not reach the threshold of $p < .10$. Statistical significance is shown ($N = 21$), although we only needed to generalize within this sample, rather than a larger population. Thus, all coefficients were used to compute the predicted values.

Figure 3 shows comparisons between actual and predicted frequencies for the leadership

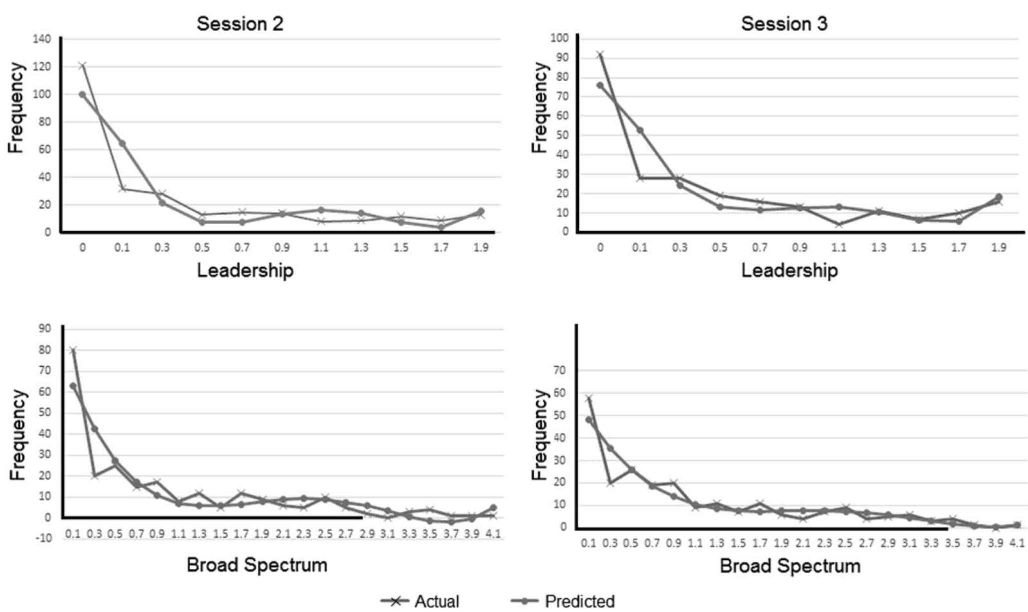

Figure 3. Comparison of actual and predicted frequencies for the leadership question and broad spectrum.

question and broad spectrum. The prediction equation for leadership in Session 2 located the secondary leaders at a score of 1.1, and the primary leaders at 1.9. Antimodes were located at 0.5 and 1.7. The prediction equation located the modes and antimodes in the same locations in Session 3.

The prediction equation for broad spectrum located the secondary leaders at a score of 2.3 and the primary leaders at 4.1. Antimodes were located at 1.5 and 3.7. The prediction equation for Session 3 located the antimodes and secondary leaders slightly further to the right of the graph although the modes and antimodes were not clearly visible in the figure.

Swallowtail Model for Leadership Changes Between Sessions

In the swallowtail model for leadership changes between sessions (see Table 7). The number of monsters killed was once again tested as the bias variable, team size as the bifurcation variable, and broad spectrum as the asymmetry variable. Coordination demand and team support were also tested as asymmetry variables. This regression analysis was conducted using the backward elimination process with the cubic term dropped. The results supported hypothesis 8 for all control variables except team support.

The linear comparison models are summarized in Table 8. The leadership rating in Session 3 was predicted from the leadership rating in Session 2 and the control variables that were retained in the swallowtail model. Again, the backward elimination procedure was used for these regression analyses. The R^2 for the pre-post model ($R^2 = .844$) was higher than that obtained from the swallowtail model ($R^2 = .759$). This result appeared to be driven once again by the high correlations between Broad Spectrum and leadership. However, monsters killed and workload ratings dropped out of the analysis for the linear comparison model.

The swallowtail model was much stronger for predicting differences compared to the linear difference model ($R^2 = .191$). Nevertheless, the variables that were retained in the linear difference model were broad spectrum, team size, TLX frustration, and GWL coordination. Leadership ratings increased if the broad spectrum score was higher and if the groups were larger. Leadership ratings declined if the individual reported greater frustration and coordination demand among the team mates.

A comparison of the R^2 coefficients for the three models indicated that leadership ratings were relatively stable between sessions. In other words, people stayed in the same roles more than they changed. The correlation between leadership ratings across sessions was $r = .501$ ($p < .001$). Indeed 88.8% of nonleaders (68.6% of the total sample) did not assume a leadership role in Session 3. Mobility was observed in 20.2% of ER participants overall.

Table 7
Swallowtail Catastrophe Model for Leadership Changes

Variable	β	t
$R^2 = .759$ (adj. $R^2 = .751$), $F(7, 204) = 91.859$, $p < .001$		
z_1^4	−.334	-4.595^{***}
$z_1^2 \times$ Monsters Killed	−.166	-2.375^{*}
$z_1 \times$ Team Size	−.302	-5.171^{***}
Broad spectrum	.752	19.194^{***}
$Z_1^2 \times$ TLX Performance	.190	2.015^{*}
$Z_1^2 \times$ TLX Frustration	−.098	$-1.694^{\dagger}$
GWL Coordination	−.311	-5.438^{**}

Note. TLX = NASA Task Load Index; GWL = group workload.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 8
Linear Comparison Models for Leadership Changes

Variable	β	t
DV = Leadership in session 3		
$R^2 = .844$ (adj. $R^2 = .842$), $F(3, 208) = 374.639$, $p < .001$		
Broad spectrum	.906	25.723^{***}
Team size	.117	3.858^{***}
Leadership, Session 2	.096	2.893^{**}
DV = Leadership Differences		
$R^2 = .191$ (adj. $R^2 = .175$), $F(4, 211) = 12.196$, $p < .001$		
Broad spectrum	.451	6.426^{***}
Team size	.131	$1.869^{\dagger}$
TLX Frustration	−.140	-2.147^{*}
GWL Coordination	−.124	$-1.950^{\dagger}$

Note. TLX = NASA Task Load Index; GWL = group workload.
$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Discussion

Though a solid foundation of research on leadership emergence exists, no studies to date have examined how leaders' perceptions of workload impact how and when they lead. Importantly, the emergence of any one person as a leader depends in part on their willingness and capacity to take on the role and who else is in the group.

Although distinctions between primary and secondary leadership roles were reported long ago (Cattell & Stice, 1954), theories of leadership emergence that assume only linear changes over time are inadequate for capturing the process underlying their emergence. The swallowtail catastrophe model, which represents a nonlinear dynamical process, captures the intrinsic dynamics of a social unit as it changes from a leaderless group of relative strangers to one with a social structure containing both primary and secondary leaders. Unlike linear models, which assume that all variables have an equivalent function that simply add up to a result, the swallowtail catastrophe model assigns different functions to its three control parameters. The research variables (conversational contributions, workload sources, and contextual influences) then play one of those three roles. The assignment of research variables to control parameters is based on strong hypothesis testing, extant theory, and prior research rather than a blind empirical assignment that is based on testing all possible combinations of variables and control parameters.

Leadership Emergence Process

Hypothesis 1 predicted that a swallowtail distribution would emerge for leadership ratings with experimental sessions. The hypothesis was confirmed, although the swallowtail structure was more fully developed in Session 3 as indicated by the significant quintic term that did not occur in Session 2. Given that teams are expected to evolve over time (e.g., Fleştea et al., 2017; Gersick, 1988; Poole, 1981; Wheelan, 2009), a stronger swallowtail effect in Session 3 was not surprising.

Hypotheses 2–4 replicated what was known about the control variables from previous research. Most of the conversational contributions assessed in the postsession questionnaire contributed to a broad spectrum factor that behaved as the asymmetry variable in the model. Task difficulty, which was operationalized by the experimental condition of one or two monsters instead of one, also contributed to the asymmetry factor. The asymmetry factor separated the nonleaders from the portion of the response surface that contains primary and secondary leaders and the transitions between those two roles. Participants who displayed more of the broad spectrum were more likely to emerge as leaders.

Primary leaders were less like to emerge when task difficulty was higher. Difficulty was reflected in the relatively poor performance of teams in the two-monster condition. ER teams prevailed against one monster 53.7% of the time, but only 16.5% against two monsters. Thus, the axiom that "no one volunteers to be the leader of a losing cause" probably applies.

Group size contributed to the bifurcation parameter as expected in hypothesis 3. The bifurcation parameter described the movement of individuals within the leadership range of the surface from an unstable or ambiguous role to one of the specific attractor positions associated with primary and secondary leaders. Larger separations occurred in larger groups. The effect was stronger in Session 3.

Group performance contributed to the bias parameter as expected in Hypothesis 4. Primary leaders were more likely to come from teams that killed more monsters during a session. Thus, a group's perception of a leader's efficacy is related in part to the success of group, even though other group members participated in the decisions.

Workload, Leadership Emergence, and Change

Hypotheses 5–7, which stated that leaders would experience greater workload, held true for the number of monsters and some but not all ratings of workload. The bivariate correlation analysis (see Table 2) showed that participants with higher leadership ratings experienced greater workload from the effort required and frustration. Leaders also reported greater coordination demand in Session 2 and lower demand for team support in Session 3. Although the more specific hypotheses concerning workload as control variables within sessions were not supported, the results confirmed the role of workload, however, when *changes* in leadership across session were examined.

Hypothesis 8 stated that all the hypotheses for the within-session analyses would hold true for the leadership change analysis; this hypothesis was supported. The asymmetry variables were broad spectrum and GWL coordination, and these variables separated leaders from the nonleader group. Leaders exhibited a greater range of conversational behaviors and reported less coordination demands. Team size was again the bifurcation variable. The bias variables were monsters killed (team performance), TLX performance demand, and TLX frustration. The two linear regression analyses clarified the net effect of the control variables. Specifically, those who improved their standing as leaders also exhibited a greater range of conversational contributions, came from larger teams, were less frustrated with the task workload, and perceived less coordination demand in the group.

Swallowtail Versus Linear Paradigm

Nonlinear models are useful because they offer deeper explanations of how phenomena change over time. If the explanations are better, their predictive accuracy should be higher than what can be attained from a linear model composed of the same research variables. It is possible to encounter trade-offs in which a linear model could produce a higher R^2 but features of the nonlinear model may explain events that are not explained through conventional frameworks. Linear models either explain very little about dynamic processes, or they explain every process as happening the same way. By the same token, a high degree of accuracy for a nonlinear model without all its critical parts properly represented would reflect an incomplete picture; in those cases, one is encouraged to either find a different model or an alternative approach to testing the chosen model.

The swallowtail pdf had a high level of accuracy as evidenced by $R^2 > .99$, thus supporting the nonlinear structure of leadership emergence and replicating previous research (Guastello, 1998, 2010b, 2011; Guastello et al., 2005; Zaror & Guastello, 2000). There is no linear counterpart to this test, however. The pdf test alone does not include the roles of control variables. The within-session swallowtail models containing the control variables identified earlier in Guastello (2010b) were supported by R^2 values of .74 in both cases. The model for Session 3 was stronger in the sense that significant weights were obtained for all parts of the model, thus indicating their unique contributions.

The R^2 for the linear counterparts to the within-session models were .82 in both cases. The broad spectrum variable alone accounted for 81% of the variance in leadership ratings, leaving only small effect sizes possible for other variables. The high degree of association between broad spectrum and leadership ratings was attributed, at least in part, to the distribution of broad spectrum ratings, which were also swallowtail-distributed.

The swallowtail model for change in leadership across sessions, which contained the core control variables plus workload variables, was supported by an R^2 of .76. The swallowtail did a much better job than the linear model of explaining change ($R^2 = .19$). The linear prepost model, which predicted Session 3 leadership from Session 2 leadership plus other variables, was still more accurate ($R^2 = .84$). This combination of results indicated that leadership ratings and social role mobility remained constant more often than they changed. However, the prepost model did not find any workload effects, whereas both change models did so. The implication is that workload issues might not affect a person's propensity to assume a leadership role on initial encounters but might give the individual second thoughts about doing so eventually.

Limitations and Future Research

Leadership and measurement. The constructs and measurement strategy for leadership behavior ratings that were first introduced in Guastello et al. (2005) and adopted here were intended to by-pass extant measurements of leadership perception that were predicated on theories of leadership style that would only be applicable in a real-world context that produced much longer exposure to particular leaders. For instance, given the nature of newly form groups in a 2-hr experimental session, expecting real transformational leadership would seem a bit far-fetched. The project, therefore, adopted a more granular strategy of specific behavior observations similar in some respects to that of Bales and Cohen (1979) but simpler in design.

It was also desirable to adopt a modular structure to the leadership behavior ratings that would facilitate situational items that could be added and removed; modularity would afford generalizability of the leadership emergence process across different tasks and contexts. An interesting outcome of this strategy was that emergent leaders tended to exert a lot more control over the task and situation compared to other team members (Guastello, 2007b).

Psychological measurements tend to be constructed with the assumption that a normal distribution of measurements is inherent. The assumption is often wrong in an NDS process (Guastello, 2005; Guastello & Gregson, 2011). Leadership emergence is clearly not normally distributed as Figures 1 and 3 indicate. Leadership roles are relatively few compared to the entire cast of characters in the social milieu. Meanwhile, the leadership behaviors are discrete; they either happen or they do not, or they are strong enough to enhance survival in an ecological niche (in the sense of Kauffman's (1993) rugged landscape *NK*[*C*] function) or they are not. Even if the traits underlying the expressions of the leadership characteristics were normally distributed, an exponential distribution would result when the dichotomies are summed (Guastello, 1995; Simonton, 1989).

The rating protocol adopted here was also flexible for the purpose of coding and analyzing transcripts of group discussions that could also be subjected to other forms of nonlinear analysis (Guastello, 2000). In principle it should be possible to explore and develop theories of group dynamics using coordinated research strategies with real time behavior and text analysis procedures. The same recommendation has been made for studying conversations as team cognition processes in a variety of occupational contexts (Cooke, 2015; Salas et al., 2015).

The leadership question and the broad spectrum variable were not always so tightly coupled in previous research as they were here. To resolve this limitation, personality and cognitive variables could be substituted for the leadership questionnaire items in the broad spectrum factor inasmuch as individual traits contribute to patterns of overt behavior (Zaccaro, 2007). Some traits that are being actively explored for their responsiveness to workload issues include field independence, fluid intelligence, conscientiousness, anxiety, and coping strategies (Guastello, 2014; Guastello et al., 2017, 2018). Other types of behavioral schema could be examined as well. Of further interest, positive affect is thought to be an important facet of high-quality interpersonal interactions in LMX theory (Liden & Maslyn, 1998), and should also be studied further within the swallowtail model.

Subjective workload. Subjective ratings of workload are simple to use quickly, and their long history of use helps with their interpretation (Hart, 2006). Reliability is difficult to ascertain, however, because workload ratings represent states more so than traits (Helton et al., 2014), which is exactly what one would want from measurements of workload when situational demands could change quickly over time. For this reason, we compiled split-half indices of reliability for the TLX and GWL in which we treated the sets of ratings from the two experimental sessions as two halves of a greater whole. This technique permitted a better estimate of internal consistency of ratings while recognizing that the two sessions were potentially different and thus not a situation where test–retest reliability would be appropriate.

TLX and GWL, the former in particular, were developed as tools for evaluating real-world work system designs such as aircraft operation and software utilization. As such, they provide useful comparisons of designs and prototypes. They are usually deployed with short-term exposures to the systems. Researchers might want to consider using or developing rating protocols that span days or weeks, perhaps when target tasks are embedded in workflows of other tasks. To revert to our opening example, workload associated with the leadership role in one task assignment needs to be evaluated in conjunction with workload associated with other production demands.

System issues. Although the short-time horizon for establishing a social structure and leadership emergence in the present study appeared to be enough to detect emergent leaders, longer time horizons could be much more informative with regard to changes in leadership and social structure, particularly when punctuated equilibria are possible. Future research should adapt the laboratory model to real-world work groups and their projects, time horizons, and workload concerns.

Conclusion

The three-way connections among workload, team performance and attributions of leadership require further study. Many leadership studies have been reported in which leaders were already formally hired or appointed, teams varied in performance outcomes, and leaders were compared with regard to various traits or behaviors (Kozlowski & Ilgen, 2006). Significant differences lead one to draw conclusions regarding what the leaders contributed to the situation. In NDS theory, however, the notion of causation is usually not that simple. Different types of control variables have distinct effects in nonlinear dynamical systems. The control variables work together with the current status of the system to produce a new result. In the specific case of leadership emergence, the entire social structure and its environmental context is operating such that emerging leaders are epiphenomenal of the whole system. It then becomes just as reasonable to say that the leaders emerged (partly) because the team was highly functional. What could happen when a leader is removed from an otherwise high-functioning team? Perhaps this slice of life is not unfamiliar: “We had a great week at the office.” “Why, what happened?” “The manager was away on a business trip and we got *so much work done*!”

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