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Modeling High-Resolution Broadband Discourse in Complex Adaptive Systems

Kevin J. Dooley,[1,3] Steven R. Corman,[1] Robert D. McPhee,[1] and Timothy Kuhn[2]

Numerous researchers and practitioners have turned to complexity science to better understand human systems. Simulation can be used to observe how the microlevel actions of many human agents create emergent structures and novel behavior in complex adaptive systems. In such simulations, communication between human agents is often modeled simply as message passing, where a message or text may transfer data, trigger action, or inform context. Human communication involves more than the transmission of texts and messages, however. Such a perspective is likely to limit the effectiveness and insight that we can gain from simulations, and complexity science itself. In this paper, we propose a model of how close analysis of discursive processes between individuals (high-resolution), which occur simultaneously across a human system (broadband), dynamically evolve. We propose six different processes that describe how evolutionary variation can occur in texts—recontextualization, pruning, chunking, merging, appropriation, and mutation. These process models can facilitate the simulation of high-resolution, broadband discourse processes, and can aid in the analysis of data from such processes. Examples are used to illustrate each process. We make the tentative suggestion that discourse may evolve to the "edge of chaos." We conclude with a discussion concerning how high-resolution, broadband discourse data could actually be collected.

KEY WORDS: broadband discourse; communication; self-organization; complex adaptive system.

[1]Laboratory for Organization, Communication, and Knowledge Studies, Arizona State University, Arizona.
[2]Department of Communication, University of Colorado, Colorado.
[3]Correspondence should be directed to Kevin J. Dooley, Department of Management, Box 874612, Arizona State University, Tempe, Arizona 85287-4612; e-mail: Kevin.Dooley@asu.edu.

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INTRODUCTION

Numerous researchers and practitioners are using complexity science to better understand organizations and social systems (Anderson, 1999; Dooley, 1997; Eoyang, 1997; Guastello, 1995; McKelvey, 1997; Poole, Van de Ven, Dooley & Holmes, 2000; Zimmerman, Lindberg & Plsek, 1998). Theories and models have emerged concerning organizational topics such as strategy (Peirce, 2000; Stacey, 1992), reaction to change (Dooley, Johnson & Bush, 1995; Goldstein, 1994), timing (Brown & Eisenhardt, 1998), cooperation (Casti, 1995; Choi, Dooley & Rungtusanatham, 2001; Guastello & Philippe, 1997; Levy, 1994; Walker & Dooley, 1999), search and creativity (Jayanthi & Sinha, 1998; Levinthal & Warglien, 2000), and dynamics (Cheng & Van deVen, 1996; Dooley & Van de Ven, 1999; Feichtinger & Kopel, 1993; Thietart & Forgues, 1995). A basic assumption within these theories is that organizations are complex adaptive systems (Anderson, 1999; Axelrod & Cohen, 1999), composed of semiautonomous agents that seek to maximize fitness by adjusting interpretive and action-oriented schema that determine how they view and interact with other agents and the environment.

The field devoted to the analysis of such systems, complexity science, may have never come into existence without the help of computer simulation. Chaos theory was (re-) discovered using analog computer simulation, fractals were realized by computer visualization, rugged landscapes were discovered by simulating the dynamics of populations of genotypes, and partial inspiration for the concept of complex adaptive systems came from the simulation of cellular automata. One of the most cited operational definitions of a complex adaptive system, Holland's (1995), is also a specification for the computer simulation language "Swarm."

Much has been learned via simulations of complex adaptive systems that use very simple models of human behavior. For example, it is common to model human behavior using a single binary state (e.g. cellular automata) models of political preference (Bousquet, Lynam & d'Aquino, 2000), or the transmission of disease (Green, 1993), or a single binary action (e.g. the prisoner's dilemma, Axelrod, 1984). In such instances, human communication at worst is ignored, and at best is assumed to be a "black box" that diffuses the influence of these states or actions into a local neighborhood of other agents. The evolutionary rules governing these systems can sometimes be changed so that they better mimic the frailties and complexities of human communication. For example, game-theoretic formulations can capture some of the politicking that is indicative of human systems (Casti, 1995), and agents can be programmed to have limited and imperfect memory, mimicking a human's bounded rationality (Dautenhahn & Coles, 2001).

An example of how simulations of complex adaptive systems treat human communication is illustrated by the program of research by Levitt and others concerning the modeling of design (and other task oriented) teams (Levitt et al., 1994). Their early work used a discrete event model, which constrained them to model the agent as simply a processing unit, performing work queued up in front of them, and communicating with other agents. Tasks comprise a project, and project tasks are represented by a work breakdown structure, thus showing temporal precedence. Communication is solely task-related (it is part of what is required to complete a task) and modeled as an activity that can be queued if the agent is currently "busy." An organizational structure defines the communication network, and tasks define the required communication acts—thus different structures may facilitate certain types of projects (with required communication patterns) better or worse. Various variables include the organizational structure, the speed and quality of communication, the speed of information processing, and the scheduling rules used by agents to select work in their queue.

This general approach has been built upon by the research teams using the computer simulation language SOAR (Carley & Prietula, 1994). SOAR models the behavior of a single agent, and stems from the marriage of cognitive psychology and artificial intelligence. SOAR's behavioral rules are rooted in Simon's work on bounded rationality (March, 1994) and Newell's representations of cognitive processing (Newell, 1992). In various implementations of SOAR, agent "knowledge" is codified by information about how to perform tasks (e.g. where a certain part resides in a warehouse), and agents may communicate and thus cooperate by asking and answering questions about such information. Agents may also ask other agents to take tasks away from them, or trade tasks.

Despite these advances, computer simulation of complex adaptive human systems still treats communication too simply. The validity of existing formulations is limited to situations where "work" or activity is well defined and relatively deterministic, so that humans can be modeled more or less as mechanical entities unable to interpret messages or exercise creative agency. Modeling communication as message passing is adequate in such situations. However, to the extent that language and discourse may play an important role in the dynamics and behavior of the social system, better models of human communication are needed.

In a human system, discursive processes have two characteristic traits that must be taken into consideration, when either modeling data from discursive processes, or simulating discursive processes. First, discursive processes occur in human systems continuously; not only do formal meetings and pronouncements shape future activity, but also mundane events such as so-called casual conversations can have immense and unpredictable consequences. Therefore, we must model discursive processes at *high-resolution*, capturing actual dialogue, not just ethnographic summaries of discourse. Yet our research methods are inadequate for this task: Ethnographic observation tends to produce summaries of discourse or a small number of events, while survey methods at best capture members' recollections of interaction. Second, most human systems consist of many people, and these people are often separated by space and time; yet, their action is in some sense coordinated and controlled such that they can be considered members in a single system. The coherence of a system in based in part on members in one locale depending on those in other locales (McPhee & Zaug, 2000), but discourse in such physically and socially separate places likewise produces divergent ideas and conceptualizations. A model of discourse should capture these *broadband* (i.e. system-wide) processes.

We propose that a basic evolutionary model can fulfill these requirements. Variations in ideas, conceptualizations, and narratives (texts) occur in a variety of ways, always through a process of conversation (broadly defined) between human agents. Certain texts are deemed less fit than others according to a multitude of criteria, and are selected out of the population. Useful texts are retained for future use. In this paper, we model texts as networks, and specifically focus on processes of variation, and identify six such processes—recontextualization, pruning, chunking, merging, appropriation, and mutation. These process models can facilitate the simulation of high-resolution, broadband discourse processes, and can aid in the analysis of data from such processes. Examples are used to illustrate each process. We also offer the tentative suggestion that discourse processes may evolve texts so that their complexity is moderate, in the region between order and chaos; some preliminary data provides support for this suggestion. We conclude with a discussion concerning how high-resolution, broadband discourse data could actually be collected, and discuss methodological, analytical, legal and practical, and ethical challenges.

CHARACTERISTICS OF DISCOURSE IN HUMAN SYSTEMS

Discourse, in the form of written and verbal communication, is central to organizing: "Organizations are made to tick through talk" (Boden, 1997, p. 23). Communication is the central factor that makes a set of group activities into a complex organization (DiMaggio, 1991; House, Russo, & Thomas-Hunt, 1995). Organizations "are processes of communication" and discourse analysis is the "means to discovering the interactive bases of organizational phenomena" (Tulin, 1997, p. 101). Gronn (1983) summarized it well when he said we should think of "talk as the work" (p. 1). We would add that we should also think of "work as the talk": If organizing is the coordination and control of individual and collective action toward some relatively common goal, organization can primarily be accomplished communicatively. To understand complex organizational dynamics, then, we must attend to processes of human communication.

Two basic characteristics of human communication, *resolution* and *bandwidth*, create special challenges for modeling, simulation, and analysis. To see this, consider the example of ethnography (Hammersley & Atkinson, 1983), which is widely regarded as one of the richest methods of organizational research. The nature of the ethnographic process is to observe events, describe them, and interpret their meanings. These goals all involve categorization and summarization. Moreover, because the ethnographer is only human, he or she naturally allocates limited attention to the events that are deemed most important. Thus, the ethnographic research process, of necessity, filters out details of the communication process in order to draw higher-level conclusions about what it "going on."

But this approach probably glosses-over exactly the events that are most responsible for shaping complex systems. Nonlinear effects exist, thus a seemingly small act can have large impact, especially when the system is far-from-equilibrium (Prigogine & Stengers, 1984). If complex human systems display, for example, self-organized criticality (Bak & Chen, 1991), then it may be necessary to observe conversational "grains of sand" in order to understand the system's behavior. One cannot determine a priori which conversations or events are likely to be important. A discursive event may be public or private, may involve few or many people, may be casual or formal, may be predicated on previous discourse or not, and so on. Yet, none of these attributes are necessarily correlated with the event's relative importance.

It may seem that all we need to do is to simply attend to the details of conversation. Indeed there is a whole branch of social science methodology devoted to the close-order analysis of communication. It is referred to under various labels such as discourse analysis (Shiffrin, 1994) conversation analysis (Boden, 1997) and interaction or sequential analysis (Bakeman & Gottman, 1986). All share a common trait: Intense microanalysis of conversation through the application of coding schemes to small units and subtle features of communicative behavior. This involves trained human judgment, so it is very time consuming. Thus, volumes are written about isolated cases of communication like a few meetings (Boden, 1997), or the openings of telephone conversations (Hopper, 1992). This approach solves some of the limitations of ethnography mentioned above. However, it has its own problems that are no less worrisome for a complex systems approach. By focusing all of its attention of the very most microlevel details of discourse, it lacks an ability to discern medium and low frequency dynamics—the sampling rate is simply too high.

Both ethnographic and discourse analysis approaches have a common problem: The limited bandwidth of human observers. Human systems, especially tightly coupled ones like organizations, behave and structure themselves according to the (often) simultaneous action of their participants. *Simultaneity* is the result of discursive processes that operate at the same time but whose participants are separated in space—simultaneity can be a major source of complexity in human systems (Weick, 1979). Simultaneity can arise when multiple subunits work on the same problem, when cooperation is required to solve interdependent problems, or when seemingly unrelated events turn out to be mutually relevant. Parallel organizational cognition can be crucial in preparing for large-scale cognitive change or in producing knowledge developments that complement or compete with one another. Simultaneity effects exist whenever there are multiple sites, with multiple agents, involved in a process. The influence of knowledge and activities in any one site spreads more or less slowly to others, as different implications take different amounts of time to process. Every site's local environment of action is different. Simultaneity also involves parallel development, which can mean more rapid development but also introduces coordination and political problems between sites. The problem of simultaneity is a key one separating the local from the global system levels. Large-scale social structure no doubt evolved and evolves partly in response to this problem. Existing ways of studying discourse, because they rely on human observers, are incapable of "being everywhere they need to be" to study simultaneity. Any model that recognizes human discourse as a complex system must have high bandwidth in order to deal with simultaneous phenomena.

TEXT AS A NETWORK

First, let us recognize that any model of such a complex phenomenon as discourse is necessarily an oversimplification, but such a model can be useful nevertheless. All models require symbolic representations of the phenomenon in question. The continuous nature and simultaneity of human discourse demand that any such representation of discourse be capable of efficiently and effectively capturing enormous amounts of textual data. The representation should also enable effective computational manipulation and analysis, and simulation of discourse processes. Finally, the representation should facilitate the modeling of dynamical patterns of evolution and change.

Representing a discourse artifact (i.e. text) as a network (e.g. Danowski 1982; 1988; 1993) provides five advantages. First, networks of text are "thick descriptions." Rather than summarizing a text by its key words, text networks retain all of the words (with the exception of stop-words like "the," "and," etc.), and show their interconnectivity. Second, text networks can be easily analyzed for interesting structural characteristics using graph theory and social network analysis methods. Such an approach has a precedent in semantic network analysis (Carley & Kaufer, 1993; Lund & Burgess, 1996). Third, when text is represented as a network, one can co-analyze the social network and the textual network via correspondence analysis (Weller & Romney, 1990). Fourth, networks can be efficiently represented and manipulated easily in a computer. Finally, a network representation enables one to frame a model of how text evolves dynamically, as we shall demonstrate.

Centering Resonance Analysis (CRA, Corman, Kuhn, McPhee, & Dooley, in press) is one way to represent text as a network. CRA draws on centering theory (Grosz, Weinsteain, & Joshi, 1995) in assuming that competent authors/speakers generate utterances that are locally coherent by focusing their statements on conversational centers (McKoon & Ratcliffe, 1998). It identifies centers (noun phrases) in text, and links the component words (tokens) into a network. CRA has been demonstrated to have convergent, divergent, and face validity (Corman et al., in press), and has been shown to capture the manner in which a collective of individuals frames their interpretation of a text (Kuhn, 2000). Note that a CRA network is an exact representation of the words as they are used in discourse, as opposed to a conceptual abstraction of the discourse as contained in representational models such as semantic networks (Carley, 1997). An example network (of a conversation with Albert Einstein) is shown in Fig. 1.

A network representation allows for a more sophisticated estimation of a word's *influence* in making a text meaningful or in creating resonance between two or more texts. Most textual analysis assumes that the influence of a word is related to its frequency (Baeza-Yates & Ribeiro-Neto, 1999). This completely ignores the location of the word within a semantic context. Corman et al. (in press) propose using betweeness-centrality (Freeman, 1979) as a measure of a word's influence. Thus, influence is related to the extent to which a concept connects other concepts that would otherwise be disconnected. Using this operational definition, the influence of a word is related to its ability to span conceptual boundaries; it also means that the most influential words represent the structural centroid of the network.

Consider the following sample text shown below; in this text, the word "correlation" occurs only once, but it is influential in that it connects concepts that would otherwise remain unconnected.

> Our company manufactures medical gowns for surgeons and doctors. The gowns are purchased from a supplier, and we apply a special protective *coating* to the gown in order to let air into the garment, but at the same time, keep potentially harmful

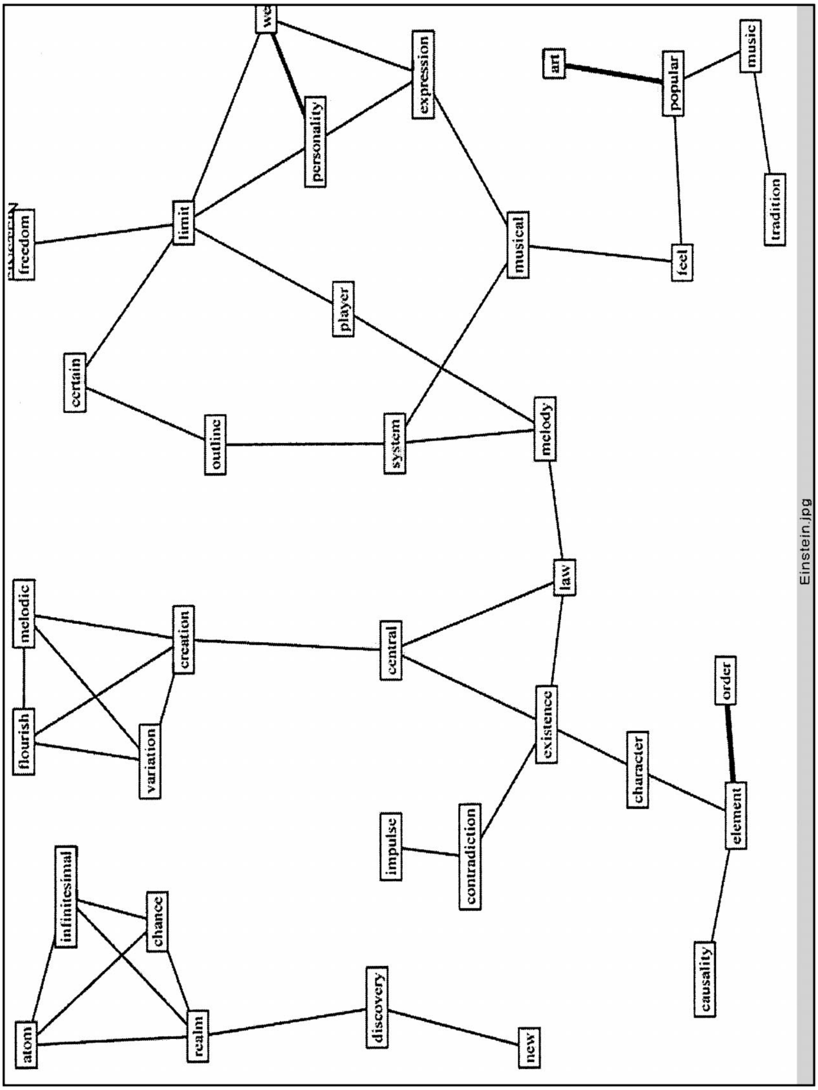

Fig. 1. An example of a Text Network: An interview with Albert Einstein.

> microbes on the exterior of the *garment*. The *coating process* is actually done in a somewhat *continuous* fashion. Several different particle *types* are heated to a *liquid state* and then mixed. This mixture is then spread evenly across the *garment* by using a *high pressure* **spraying** *process*. Our *challenge* is to control the *quality* of this **spraying** *process*. We can take sample measures of *coating* thickness and uniformity and plot them on *statistical control* charts. But we notice a few problems. *One* is there is a **great** *degree* of autocorrelation between samples we take over short *periods* of *time*, and another is that there is a **great deal** of CORRELATION between **parallel sprayers**, as *multiple* **sprayers** draw *liquid* from a *common* hopper. How can we appropriately develop a *statistical process control plan* for this *process*?

The word itself is capitalized; first order connections (direct connections within the network representation) are bolded; second order connections can be found by expanding all of those nodes, and are underlined; and third order connections can be found by expanding of the nodes identified previously, and are italicized. Note that because words co-occur in different spots of the text, this diffuses local meanings globally throughout the text. One can see that the term correlation connects to many words in the text three-steps out. In fact, it is the "correlation" present in the process that makes this problem "hard," so it truly is a differentiating fact in the production of textual coherence.

THE EVOLUTION OF TEXTS IN COMPLEX ADAPTIVE HUMAN SYSTEMS

We propose that discourse is the process by which texts evolve in complex systems over time (Bastien, McPhee & Bolton, 1995). Specifically, evolutionary mechanisms can be used to model this dynamical process, in a way analogous to the evolution of memes (Lynch, 1996). Evolution consists of processes of variation, selection, and retention. When variations occur, texts are selected based on various fitness criteria, and are retained through processes of discourse, which recreates those text, albeit likely with variation. Selection criteria may include resonance with previous discourse, resonance with existing beliefs and norms, informational value, entertainment value, or complexity (i.e. related to its ability to be understood and/or remembered). Because of the high likelihood of variation occurring, and because selection forces may be extremely weak (agent heterogeneity leads to heterogeneity in fitness functions), it is likely that texts do not retain much of their original form unless they are reproduced exactly in a written format. We shall focus our discussion on how processes of variation may occur.

Variation can occur through two processes: recombination and mutation. In a text network, recombination involves aggregating portions of one network with another to form a new network. Influential words may play an important role here, because they represent potential cut-points, where semi-independent parts of a network can be broken off and moved elsewhere. Mutation involves the changing of a portion of an existing network.

Recontextualization occurs when a word is retained as an anchor around which meaning is built, but the structure around that word changes. It involves placing the influential word into a new context, therefore giving the word new meaning. It occurs when it is desirable to retain the anchor, perhaps because of historical value, but one wants to add or change the meaning implied by the anchor. An example can be found in Juran and Gryna's (1994) influential textbook on quality, "Quality Planning and Analysis." We examined the preface of two successive editions of the book, one from 1970 and one from 1994. During this time, the practice of quality in industry had undergone significant change (Dooley, 2001). In both text networks, *quality* is by far the most influential term (although its influence approximately doubles in the later edition), and the most frequent (it occurs about 100 times in both editions).

The words connected to *quality* in the 1970 version of the book were: *chronic*, *department*, *function*, *time*, *fitness*, *label*, *user*, *same*, *design*, *problem*, *concept*, *activity*, *control*, *company*, *use*, and *product*. In the second edition, the words attached to *quality* were: *product*, *customer*, *manufacture*, *process*, *change*, *component*, *feature*, *function*, *good*, *high*, *cost*, *concept*, *service*, *force*, *system*, *spiral*, *task*, *approach*, *condition*, *basic*, *definition*, *organization*, and *program*. The only words in common are *product*, *function*, and *concept*. The concept of quality has been recontextualized, moving from *problem* and *control* to *process* and *system*; from *company* to *organization*; from *department* to *manufacture* and *service*.

Another form of recombination is *pruning*. Pruning involves the trimming of a network, so that the new network is smaller, perhaps quite a bit smaller, than the original network. Pruning may be done intentionally, or it may naturally occur as people attempt to simplify their communications and remember important and/or significant facts—it results from human's natural need to filter the vast sensory data that is ever present. Pruning may involve a faithful summarization of the original text, or it may represent a highly filtered view of the original text that is specific to the listener or speaker. For example, sometimes the "details" or portions of a narrative may be intentionally left out by a speaker; in other instances, even the core message of the text may be transformed during the trimming process, so that a different meaning is conveyed.

An example of pruned text is Deming's 14 points (Deming, 1986). W. Edwards Deming was a highly influential quality consultant in the latter part of the twentieth century, who helped transform the Japanese economy in postwartime by teaching them the concepts of continuous quality improvement. His discourse with organizational members covered a vast array of ideas and concepts, dealing with everything from supplier management to fear in the workplace. His clients constantly requested that he "boil down" his message to a list of key principles, so that it could be more easily remembered and communicated (Walton, 1986). He rejected such simplification for a long period of time, but finally capitulated and wrote his "fourteen points," which contained pruned messages such as "drive out fear," "minimize the cost of inspection," and "infuse pride of work." Pruning can be a powerful process—in this case, the development of the 14 points was probably instrumental in helping diffuse Deming's message. Other examples of pruning can be observed in mission and vision statements for organizations (e.g. "A computer on every desk"), phrases used for branding (e.g. "Just do it"), and sound bites (e.g. "I am not a crook"). Pruning may be a prerequisite to the sedimentation of themes in an organization (Bastien et al., 1995).

Chunking is a special form of pruning. Chunking occurs when a particular subset of words cooccur so often that their subgraph in the network essentially becomes a single node in itself. Often this is quite literally followed by the chunk being made into an acronym, which symbolizes its unitary essence. For example, the terms *total*, *quality*, and *management* were purposefully chunked into the term *total quality management*, which later become an acronym, *TQM*. During the chunking process, each of the terms that are merged brings along its own network of meaning (What does *quality* mean? What does *total* mean? What does *management* mean?). As the chunk evolves, it may attain meanings that are unique to it, separating it from its original roots. Continuing our example, the term *TQM* became so symbolic of rigid, programmatic change management programs that it became vilified, and people had to start using different terms to communicate about the issue in a more positive manner—for example, people reframed *TQM* as *quality management*, or as *total quality*, or as *quality improvement*.

Another form of recombination is *merging*. This is when one text interacts with one or more texts over time, and new texts emerge that combine elements of old ones and add new elements along the way. Merging is a process that has elements of both path dependency and emerging novelty (Bastien et al., 1995). It has the potential to create something new while retaining connections to the past. Merging captures two important processes of simultaneity in complex adaptive human systems. First, people who are separated by space and/or time may discuss a common set of issues that are pertinent to the global system, but because of their own idiosyncrasies and local contexts, they may evolve very different understandings and conceptualizations. When these individuals come together, a convergent process of merging may take place. Second, people often are together in space and time, and thus participate in shared experiences. As they depart from one another and converse about that shared experience, divergence in the form of de-merging or bifurcation may occur.

As an example, consider the following conversation on a listserv from 1992 concerning the topics of chaos and art. Figure 2 shows a series of panels, each depicting a different speaker turn. Only a portion of the network is shown, and words not shown as connected were not used by that speaker. Speaker A in turn 1 introduces the pair *art-chaos*. Speaker B in turn 2 actually discussed the topic in a completely different manner, borrowing no terms from speaker A (panel not shown). Speaker C recontextualizes *art* by combining it with *work*, *music*, and *creativity*, and recontextualizes *chaos* by combining it with *work*, *theory*, and *order*. Speaker E in turn 5 now merges the networks from speakers A and C, by recombining *art* and *chaos*, and retaining several of the links established by speaker C. Speaker B in turn 6 maintains the link between *creativity* and *chaos* but merges it with something of their own making, and finally speaker C in turn 7 prunes their original network (in turn 3) by maintaining the *work-chaos* link and the *music-art* link. This example demonstrates that several of the processes can occur in parallel or sequence.

A further form of recombination is acquisition, or *appropriation*. Appropriation is similar to cloning or asexual reproduction, in that a portion of a network, or its entirety, is taken from one text and combined with another, with little or no change. Appropriation differs from merging in that connections between centering tokens are expected to change during a merge, while they remain the same during an appropriation. Appropriation occurs when the value of a text is tied primarily to the interconnections of objects within the text, rather than the objects themselves—its value is synergistic. For example, certain legal language that is worded exactly to convey a precise meaning may be appropriated from one text to another to ensure consistency in interpretation; such templates are often referred to as "boilerplates." Organizational stories and myths that are an important part of its culture may also be appropriated in order to reinforce cultural norms and expectations, including norms of language (Martin, Feldman, Hatch & Sitkin, 1983; Mumby, 1987).

An example of appropriation combined with pruning is reported by Mizruchi and Fein (1999). They consider DiMaggio and Powell's (1983) essay on institutional isomorphism, and show how other authors subsequently citing the work have departed somewhat from the original intent of the theory, and have socially constructed its meaning. For example, they observe that American organizational researchers were more likely to appropriate elements of the theory pertaining to mimetic isomorphism, and were less likely to use elements pertaining to coercive isomorphism.

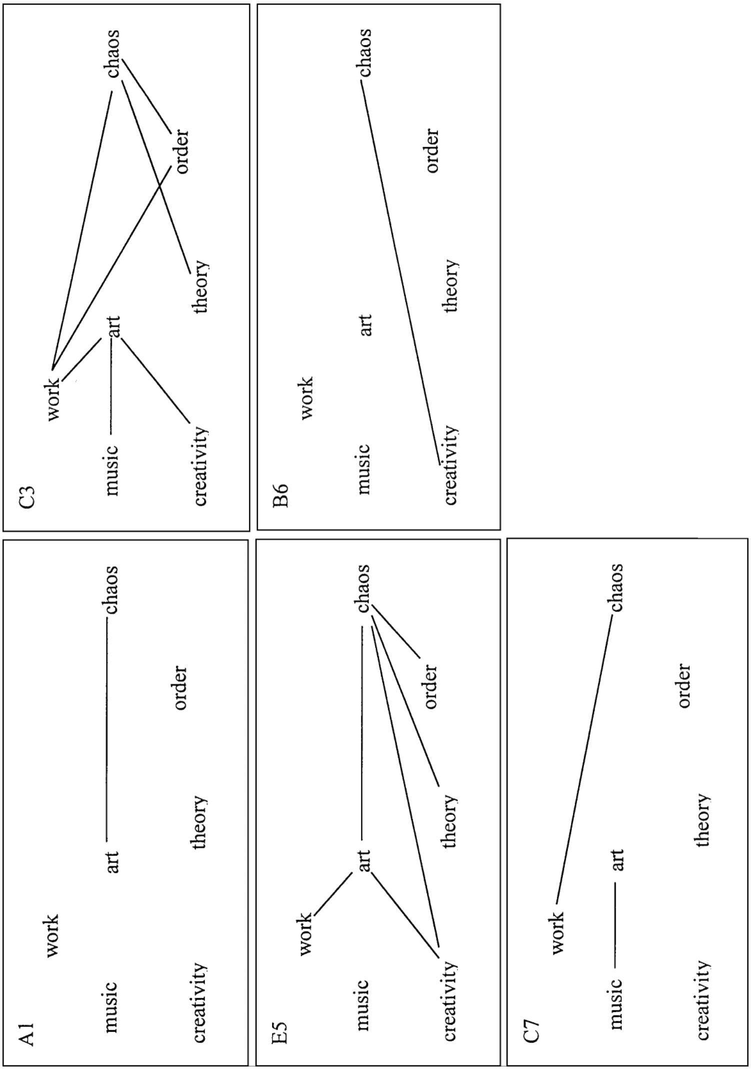

Fig. 2. Evolving text in a Listserv discussion.

Another way in which variation can occur is through *mutation*. Mutation may be intentional or accidental, and may occur to a single word, or to a portion of the network. Mutation is important because a series of small mutations may transform the meaning of the text. When mutation is combined with the other variational processes, it can lead to great divergence in the implied meaning of a text, because selection processes are typically weak. Mutation occurs because people's memories are imperfect; they filter information and communication according to their own internal schema; and people have individual preferences for particular words, based on either historical precedence or intention. For example, while the words *company*, *organization*, and *firm* all imply the same general meaning, people will use them differently. *Company* is typically used more in nonacademic settings, while *organization* and *firm* are used more in academic settings; *organization* tends to be a word used by people with psychology or sociology backgrounds, while *firm* tends to be a word used by economists and lawyers.

One of the authors observed an interesting process of mutation by playing the "telephone game" in a classroom setting. The game consists of a written story and a serial line of participants. The first person in the line read the story, and verbally passed it on to the next person in line, etc. In one instance, the story being used concerned two rare oxen that had been found in a Vietnamese forest near Hanoi. The term *oxen* mutated to *cows*, and *Hanoi* mutated to *Illinois*, which mutated to *Chicago*. The combination of *cows* and *Chicago* then led someone to recombine those two concepts with the an old "folk tale" of how the Great Chicago Fire of 1871 began, and so what started out as a story about the discovery of rare animals was transformed into a story about Mrs. O'Leary's cow who knocked over the lantern that started the fire that burnt down the city of Chicago.

DOES DISCOURSE EVOLVE TO THE EDGE OF CHAOS?

The nature of connectivity in these text networks leads us to a provocative suggestion—texts evolve in their complexity to maintain a balance between order and chaos. The region of moderate connectivity is sometimes called "the edge of chaos." We will derive this conclusion by modeling text as it located on a *rugged landscape* (Kauffman, 1993).

Consider a single text. As alluded to before, the text itself can be considered to have a certain fitness, where fitness is determined according to a number of different criteria. Consider the following question: What is the contribution of each word in the text towards the fitness of the entire text? Beginning from a CRA framework, each centering token can be considered a trait of the text. In order to be consistent with a landscape model, we must also consider each centering token that could possibly be in the text but is *not*. This word-space represents the number of traits N, or genes, in the text, or genotype. Each gene (associated with a particular word) is associated with a binary allele or value—zero if the word is not present in the text, one if it is present in the text.

There may be situations where the lack of the presence of a word contributes to the fitness of a text (for example, if the word is offensive or triggers counterproductive action), or where its absence detracts from the fitness of a text. To simplify the model, we shall not consider these specific instances. Instead, let us assume that the fitness of the whole text can be deduced from the fitness of the words present in the text. Thus, the number of nodes (centering tokens) in the text network represents the parameter N in Kauffman's landscape models.

Thus our genotype, or text, is represented by a vector of all "1"s, but each of these alleles contributes differentially to the fitness of the overall text. The second parameter that must be specified in such landscape models is K, which refers to the strength of epistatic connections in the genotype. Specifically, K is the number of genes that any given gene interacts with in terms of determining its fitness contribution to the whole. Thus a system with $K = 0$ represents a system where each gene contributes independently (additively) to fitness, while $K = N - 1$ represents the extreme case where the fitness contribution of one gene depends on the state of all other genes.

In the case of a text network, K can be made operational by examining the connections between centering tokens; specifically we propose that the degree centrality (Freeman, 1979) of a centering token can be used as an estimate of the number of other centering tokens that clarify and constrain its fitness contribution. Because we have operationalized the CRA method using a linguistic theory (centering theory), we have confidence that our estimation of connectivity here has theoretical validity.

We examined a sample of fifty texts from a wide variety of sources, ranging from texts of screenplays, to courtroom testimony, to conversations, to technical papers. These texts varied in terms of whether they were written or oral; represented one person or multiple people; were edited or not; were fiction or nonfiction; and whether the intended audience was broad or narrow. We analyzed each using the CRA method, and calculated the centrality for each centering token (node), and then found the median of those values. The median values (K) ranged from 1 to 5, and a majority (85 percent) had a median of 2. A few of the television screenplays had a median of 1 (indicating they were within the "order" regime), and several of the political speeches and collections of academic abstracts had medians of 3–5 (indicating they were in the "chaotic" regime). The average degree centrality was usually higher than the median, indicating that there were a few words with large degree, and many words with small degree. The number of nodes in each network (N) ranged from 39 to 4402, with a median of 204.

According to Kauffman's simulations, a system with $N = 200$ and $K = 2$ or 3 represents a special system—one poised at the edge of chaos but within the orderly regime. Specifically, we would expect the following type of evolutionary behavior of texts with low values of K:

- The fitness landscape contains many local optima with relatively the same overall fitness. Thus many different textual configurations are possible, all of which can be deemed "fit."
- A low value of K would keep a discursive process from dropping into a complexity catastrophe, thus fitness of the whole text could remain relatively high, even as its length increased. If this were not the case, for example if K increased as N increased, then overall fitness of text would drastically decrease as the text got longer.
- A text with a low value of K would tend to have higher fitness than a text with $K = 0$. This makes sense—a text with centering tokens that are totally disconnected from one another is likely to be of low coherence.
- Texts with high fitness will tend to be close to one another in network space. This gives credence to the effectiveness of our proposed variational processes.
- Over time, improvement in fitness tends to come from local as opposed to global search processes. This means that texts may tend to stagnate and become fixed over time. We can see this with text representing stories and myths, protocol, strategy and vision, rules and regulations.
- "Long jumps"—texts that are far different than the existing population—are likely to have lower fitness, although some such jumps will create texts with higher fitness. This means that most adaptation will take place locally and incrementally. This is anecdotally confirmed by observing how similar patterns of communication are within semi-closed social systems (cliques, friendship networks, etc.) (McPhee & Zaug, 2000).
- In our context, the value of K varies widely across the network. In this case, Kauffman showed that those centering tokens (genes) that have high values of K will change first; later in the adaptive process, centering tokens that are more "independent" (low values of K, i.e. low degree centrality) are more likely to change. This makes intuitive sense. Centering tokens with high K are those terms that may also be influential. After the most influential terms are set, then

"editing" takes place on the margin, working on terms that contribute to the meaning of the text rather independently.

Finally, Kauffman suggests that $K = 2$ or 3 systems are at an evolutionary "sweet spot"—the edge of chaos. First, fitness of the overall system can remain high in light of increasing size (N)—complexity catastrophes do not occur. Second, the slopes of the fitness landscape around local optima are steep enough so that mutational processes do not overpower adaptation processes—error catastrophes do not occur. Third, while most mutations have little or no impact, a select few will have great impact, thus enabling texts to evolve radically. The impact of these mutations should distributionally follow an inverse power law. Fourth, because the most fit texts tend to be near one another, processes of recombination are useful.

These suggestions are very tentative and much more work must be done to provide evidence in support of them; yet, they are plausible given our preliminary analysis of a variety of texts. Additionally, because discourse processes work in populations of text rather than individual texts, a more rigorous examination of these issues must examine models of coevolving landscapes. Nevertheless, the initial data provides some hint that this would be a useful avenue to examine further. For example, if such suggestions were true, it implies that: (a) speakers may unconsciously structure their discourse so that key terms are placed so that they maximize their influence, (b) different types of texts may be structured differently for intentional purposes (e.g. the rhetoric of a political speech versus the banter of a television situation comedy), (c) texts may undergo "complexity catastrophes" as term connectedness is increased, and (d) mutations of texts may cause them to undergo changes in meaning, and the magnitude of such changes may be distributed as an inverse power law.

FEASIBILITY OF HIGH RESOLUTION BROADBAND DISCOURSE ANALYSIS

We have made the argument that current methods for studying human systems are not capable of modeling the essence of communication in complex adaptive systems, and that such methods are necessary if we are to understand systems operating at "the edge of chaos. Better models of complex adaptive human systems will require better models of discourse, because the most effective way to bring about radically novel theories of a phenomenon are to change the ways in which the phenomenon is measured. Philosopher C.I. Lewis (1929) states: "The determination of reality, the classification of phenomena, and the discovery of law, all grow up together" (p. 263). As measures change so do the constructs, and as constructs change, so do the theories. For example, the extended resolution obtained in observations of outer space by the Hubble telescope has transformed many cosmological theories. Likewise, if we want to develop sophisticated models of communication in complex systems, we will need to increase the *resolution* of our data, and in the specific case of complex systems, our *bandwidth*. Existing research methods such as ethnography, conversation analysis, and event history analysis do not model organizational discourse adequately. Either they lack the high resolution needed to observe the organization minute by minute, or they lack the broadband needed to observe discourse occurring in multiple places at a single time. We could benefit from a methodology—let us refer to it as *HBDA*, or *high resolution, broadband discourse analysis*. Successful HBDA would require methods capable of examining and grounding conceptualization about idiosyncratic details and contextual facts of events; and methods capable of tapping a wide range of contextual events, across real as well as social-structural space and time, throughout the segment of the organization whose processes we wish to analyze.

HBDA provides the paradigm in which organizations can be empirically observed as complex adaptive systems. Behavior in a complex adaptive system is induced not by a single entity but rather by the simultaneous and parallel actions of agents within the system itself. In a discourse-rich system, such as a formal organization, discourse stretching across time and space best captures these simultaneous and parallel actions. HBDA has the potential to study processes of emergence, namely, how local (high-resolution) actions lead to global (broadband) order.

Not all "communication" is discursive; body language and other nonarticulated actions can act as important communication media. A natural extension of HBDA would be to capture not only the "audio" portion of the organization, but also its "video." Additionally, we recognize that important communications may take place outside of the physical boundaries of the organization, and thus HBDA is limited in this sense (as is any other observational method of human systems).

The feasibility of HBDA is no idle concern: It entails unprecedented observational intensity and scope. As we have already argued, existing methods for the detailed study of organizational discourse can at best study only small, isolated groups and dyads for limited periods of time. Furthermore, the unpredictability of communication in terms of time, location, participants, and triggering events makes it unfeasible to simply scale-up these methods. Presuming a researcher could assemble, train, and fund a large team of ethnographers or conversation analysts, he or she would still miss potentially important interactions in organizations of significant size and/or dispersion. We shall discuss these challenges, organized into the areas of methodological, legal and practical, and ethical issues.

Methodological Issues

HBDA requires synchronous recording of the utterances of individual organization members at all times, regardless of their location. Such recordings can be digitally processed to yield information about who is talking to whom at what times (Corman & Scott, 1994). The voice data must then be transformed into textual data through computer-aided voice recognition or transcription. For HBDA, human transcription is infeasible (see below); computer-aided voice recognition technology, however, may progress to a point whereby transcription can be reliably automated.

Large organizations produce staggering amounts of communication. Each organizational member can produce hundreds of email messages, dozens of memos and notes, and one or more significant reports per day. Corporate intranet sites bulge with the volume of textual data archived for organizational memory. Yet this volume of written discourse in an organization pales in comparison to that of spoken discourse. Extrapolating form a study by Gronn (1983), Corman, et al. (2001) estimate that a one person's organizational communication for one work day would consume 75 pages, if transcribed. At that rate, even a small organizational subunit of 50 people would generate 18,750 pages of transcript per week. That is enough to fill 37.5 reams of paper, a stack over five feet high! Admittedly, that figure is based on an estimate, but even it is too high by a factor of two, one week of 50 people would still create a transcript so big that no one could be expected to read it. Indeed this may have even happened to Gronn, whose paper focuses on just one, 30-minute segment of his data set. An automated analysis method, such as CRA, is clearly needed for such a situation.

This volume of data also poses basic logistical problems associated with large-scale research efforts: labeling and storage of data, data retrieval, data reduction, breakdowns of recording or storage equipment, and issues of reliability and validity in data collection.

Practical, Legal, and Ethical Issues

How does one gain access to an organization and convince all employees that they should cooperate in allowing all of their discourse to be recorded over an extended period of time? Besides the obvious ethical issues (discussed below), people have legal rights that would require a HBDA project to acquire permission for all such recording; it is likely that in any organization a significant fraction of people would "opt out," for any variety of reasons, and would compromise the basic premise of HBDA. Additionally, companies are extremely sensitive to corporate intelligence efforts aimed at identifying and even stealing their organizational knowledge. If discussions pertaining to strategy were made publicly known, it could mean the failure of the company.

Even accomplishing HBDA on a technical and practical level involves serious ethical concerns. We are advocating a system that would allow researchers or others with access to it to have a kind of omniscience, the ability to "listen in" on all of the communication, everywhere in an organization, at all times. There is nothing inherently unethical about doing this, especially in a research setting, done under conditions of informed consent and institutional review, with proper legal protections and safeguards for the participants.

However, it would be naïve to assume that all future uses of such a system would be benign. Trethewey and Corman (2001) argue that applications of knowledge technologies are most ethical when they are inclusionary and transparent, and that technologies often start out this way. However pressures for knowledge efficiency and behavioral efficiency drive organizations to make knowledge systems opaque and/or exclusionary. Systems that are *both* create the conditions for panoptic surveillance, the classic "big brother" application. While ethical behavior on the part of technology users can prevent such misuse, it is important to realize that the increasing tendency to treat knowledge as a commodity will create pressure to sacrifice ethics for efficiency, making panoptic control an attractive nuisance (Botan, 1996). Understanding these tendencies and planning to deal with them will be a central issue in developing systems for HBDA.

SUMMARY

Following a contemporary trend in the study of organizations (Putnam et al., 1996; Taylor, Flanagin, Cheney, & Seibold, 2001), we argued that human systems are created, maintained, and transformed in and through discourse. From this perspective, communication is both medium and outcome of organizing processes. Consequently, discourse itself is a complex phenomenon; yet, the richness of this dynamic and interpretive process is often lost in existing models of complex adaptive systems. Simulations using these models tend to either reduce communication to message transmission or assume simple influence effects on nearby agents. For those interested in understanding and explaining the action of human systems over time, simplistic conceptions of discourse—the central process is organizing—must be abandoned.

One approach to gaining greater purchase on the discursive construction of human systems is to conceptualize discourse artifacts (texts) as networks. Representing texts in this way shows the interconnections among words in the text, and is amenable to useful network analysis methods and visualization techniques (Wasserman & Faust, 1994). The specific representational approach introduced here, Centering Resonance Analysis (CRA), draws on a linguistic theory of discourse coherence to parse a text into its constituent noun phrases. From this, CRA is able to display the connections between noun phrases and highlight words of varying influence in a way that extracts meaning from discourse to facilitate comparisons between texts and trace discourse variations over time.

In human systems, it is likely that texts produced by members evolve in ways that exhibit the basic evolutionary processes of variation, selection, and retention. With several examples, we provided evidence of phenomena displaying recombination (comprised of recontextualization, pruning, chunking, merging, and appropriation) and mutation in text networks. Because evolutionary processes have been posited as characteristic of complex adaptive systems of all types (Axelrod & Cohen, 1999; Lee, 1997; Saperstein, 1997), we investigated the possibility that text networks evolve to the "edge of chaos," a region between stability and instability that may be a source for creativity and innovation in human systems (Thiétart & Forgues, 1995). Using 50 texts drawn from a wide variety of sources and a modeling technique based on Kauffman's (1993) notion of a rugged landscape, we derived several tentative (and testable) conclusions about the variational processes leading to a text's fitness in network space, as well as about how individual texts move through this space. Understanding discourse evolution, as a complex phenomenon, is key to understanding complex human systems.

To investigate the discursive construction of human systems, we proposed HBDA: High-resolution, broadband discourse analysis, which would capture all the discourse (oral and written) produced by organization members over a given span of time. Existing methodologies are simply not adequate to capture either the scope or the detail of discursive processes. Although the HBDA methodology would produce large volumes of text, CRA is well situated to represent, analyze, and compare these texts. Therefore, HBDA is an attractive and plausible possibility that, coupled with CRA, would enable researchers to deepen their comprehension of the interplay of communicating and organizing. Significant issues confront such an approach, however: the practical problems of obtaining these data, the legal restrictions that make recording communication difficult, and the ethical concerns of such a system for the individuals involved.

In the end, we propose that HBDA and CRA represent necessary approaches to adequately modeling and understanding discourse processes, and therefore to modeling and understanding human systems. Although substantial obstacles exist for such an investigation, we have shown the substantial benefit offered by our methodological call. If the potential for complexity theory to transform the study of human systems such as organizations is to be realized, there must be a novel approach to theorizing discourse, as well as to collecting and analyzing texts. The techniques proposed here encourage just such a theoretical and methodological leap.

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