# Information transmission in social groups: communication, networks, and interaction

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**Abstract:**

I argue that for information transmission to occur there must be communicative contact between individuals. The patterns of contact then provide a set of outer limits for the extent of information spread. But an examination of a formalized communication process shows that the degree of information or knowledge transmitted may be related to the degree to which the communicants share similar bases of meanings and interpretive schemata. An individual's cultural properties can be described as a set of schemata, frames, heuristics, historical meanings, and behaviors. Acts of communication among individuals lead to increasing similarity along these cultural dimensions, which may change the likelihood of future interactions, and the effectiveness of existing communicative relations. These longer time scale modifications of social structure often feed back into the process, causing systems to behave in a complex and possibly counter-intuitive manner. Ideally, the analysis of the formal properties and behaviors of such systems might shed some light on some of the observed trends and biases in human communication and the processes involved in the formation of social groups. Analyses of a study of self-report name recognition and communication networks among the incoming class at Bennington College are presented, and some implications discussed.

## I. Introduction

On April 16, 2000, a diverse group of activists, anarchists, artists, anti-corporate agitators, union members, and students converged on Washington D.C. Their common purpose, as much as there was one, was to disrupt the meetings of the World Bank and the International Monetary Fund in an attempt to draw attention to their perception of the organizations' agendas, and to encourage discussion of specific issues which were not being addressed in the political arena. The protesters hoped to build on the success of the Seattle World Trade Organization protest of November 1999, and intended to employ similar tactics . I was among a group of students from Bennington who went down to take part in the rallies. I had some idea of what to expect, but was still blown away by the intensity of the action and the experience. The details of events, political agendas, encounters and their impact upon me are not relevant here. What is important is that, at least in later considerations, the actions and interactions of those three days served to focus my interest on the relationship between communication, the structure of social relations, and human events.

Fig. 1.a Confrontation between a protester and a man who tried to cross through the line at the IMF/World Bank protest. (Washington D.C. April 16, 2000, photo by author)

I had never really been a participant in mass action before. The task of organizing, informing, and discussing the activities of several thousand people seemed at times almost impossible. Furthermore, activists at the A16 protest in Washington D.C. were attempting to coordinate action among themselves - a huge collection of diverse groups with divergent agendas - without creating autocratic leadership or explicit command structures in the

Fig. 1.b An encounter between police and protesters near the capitol. A large group of riot police just pushed through the intersection to escort several buses into the 90 cordoned off blocks around the capitol. (Washington D.C. April 16, 2000, photo by author)

traditional sense[1]. The immense amount of time and talk required to create collective action was both frustrating and inspiring - and for me it began to highlight the incredibly important, but normally transparent, role that communication and information play in our daily lives. For me the protests were a far more extreme situation than almost anything I had experienced before. The stakes were much higher. Sometimes information seemed to spread through the entire city in a matter of moments. Often it was completely off the mark. Everyone had different impressions and interpretations of what was going on. Even people standing at the same intersection had radically divergent accounts of seemingly unambiguous events: Did they just use tear gas? Who attacked first? Where did the buses of riot cops come from? And even if there was consensus on the streets about what had happened, it didn't necessarily agree with the same facts after they had percolated up through the media and emerged on the evening news.

Stress, fear, trust, rumor, and discussion were everywhere. At certain times I found myself attempting to wring every last drop of information from an idle comment, or read meaning into every gesture. Most of the people, police and protesters alike, had little concrete information to base their decisions on. I often felt that I was scrambling to make sense of what was going on, sifting scattered remarks and reports to try and assemble a coherent picture, searching for the slightest contextual cues which might affect my judgment of what was occurring. I suddenly found it necessary to evaluate the validity of everything I heard: How many mouths has this passed through? Is this information still recent? Is the person likely to be biased in their perception? I became conscious of my contacts, the people I was in immediate communication with. Who has a cell phone to contact the outside? Who has a news radio? Who went to the planning meetings today? Who might be a police informant? Who has a camera to tell this story?

My experience made me realize that it is quite remarkable how good we normally are

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[11] The activists employed what might be described as a hierarchical consensus process. Ideally, when decisions were to be made, small groups would reach consensus, each group would send a spokes-person to form a larger group which would come to consensus, and the final decision would be passed back down.

at collecting and disseminating information. To function in daily life, we must employ a tremendous range of knowledge about our social and physical environment. But, despite the fact that most of us have spent a great deal of time in formal educational situations, much of the information that we utilize in a daily pragmatic fashion is not explicitly documented or taught in a school setting. Evidently we gather a great deal of what we know about the world through some mysterious process of direct experience, observation, and inference. Yet we often have knowledge (and certainly opinions) about events or environmental states which we have not directly observed.

The communication ability with which humans are equipped allows us to utilize each others' experiences. This is something which I think we largely take for granted: we do not each need to go out and create a situation which allows us to glean the same environmental observations - in many instances we are willing to take another's word for it. To put it another way, an individual in a social group can draw on the collective knowledge of the diverse experiences and multiple life histories of each of the other members. The process of exchanging information makes it so that collections of humans can in a sense have collective properties - knowledge shared among members - without the requirement of redundant direct experience. This process of culture or social information exchange has the potential to act as a powerful knowledge amplifier. There can be an assembly or accretion of a body of tested explanations or facts which can be unquestioningly adopted by individuals and used as background for further explanation and exploration of the world. "Progress" over time can occur in part because certain aspects of knowledge about the world can become cultural properties of a group which are passed on without the associated learning costs.

That is not to say that the process occurs without error, or that individuals normally adopt views and accept information without question. I would actually argue that one of the fundamental tasks humans perform is to use their cognitive and perceptual abilities to question, filter, process, and assemble the flood of often inconsistent and conflicting information into a roughly self-consistent conceptual framework. The details of how we achieve a sense of

understanding and a useful synthesis of incoming and previously learned information are probably in the domain of cognitive psychology and are outside the scope of what I want to look at here. But I think it is useful to keep coming back to the concept of an individual who is continuously assembling interpretations of her surroundings based on her accumulated experiential knowledge and the knowledge of the people she communicates with. What fascinates me at the moment is how this creative knowledge-making process, acting simultaneously in every individual of a group, works to shape and mold the information as it moves. What forces are evident? Where does the information used in constructing knowledge actually come from? Are there patterns to what gets lost or filtered out?

If people were excruciatingly rational automatons and language allowed for instantaneous and error-free communication, we might have an instance of a omniscient "group mind" in which every person has perfect knowledge of everyone's experience. But this is obviously not the case. This may be partially due to the psychological properties of individuals, but I believe that it is also caused by the mechanics of language and the communicative process. Language is a tricky and little understood tool. I'm referring not just to its spoken and written aspects. I'm including in language the full range of processes that rely on semantics, symbols, abstraction, and approximation to convey meaning from one mind to another. When examined closely, language appears to be at the same time infinitely expressive and infinitely vague. Communication, like perception in general, inherently includes the process of extracting only the relevant aspects from information or an experience. It can never be instantaneous and lossless because it must encode the full breadth and sensuality of life experience into a brief set of understandable communicative actions. The high bandwidth of perceptual information must be compressed into a set of narrow communication channels, and this must be done with great speed and efficiency if any useful meaning is to be conveyed in a finite period of time.

When viewed in this manner, accurate or complete communication would be a limiting process which requires time and repeated instances of attempted communication to overcome

errors and bandwidth restrictions. Even in a society of compulsive gossips it is unlikely that a person would ever be able to obtain all of the facts present in the minds and culture of the other group members. There are, of course, a tremendous number of factors other than communication errors which prevent us from reaching a state of homogenous knowledge. Language, physical distance, ideology, access to media, education, and socio-economic barriers are some of the first which come to mind. All of these forces may act to drive (and in turn be driven by) patterns of interaction and communication: cultures, sub-cultures and social groups.

The information, opinions, and communal knowledge available to any single individual seemingly would depend on an almost unimaginably complex layering of context, chance, and social structure. Yet at the same time there seems to be a strong degree of order and perceivable patterns of knowledge and beliefs both at the level of individuals in a group, and at the larger scales of communities, regions, and countries. It may be difficult to give specific examples of what makes someone an American, but it seems clear that there is a degree of common experience and cultural referents - and that these may be in some ways distinct from what makes someone French. At the same time, there is a sense of universality; that there are some properties of social collections of humans which are broadly cross cultural.

This paper will attempt to sketch out some of the processes and phenomena which I believe are relevant to, need to be accounted for, or hint at, a greater understanding of information flow in human social groups. My goal is not to try to understand the full complexity of human culture and behavior. I do not anticipate being able to predict trends or make sweeping generalizations. Part of me doesn't believe that the beauty, craziness and sheer creativity of people can really be reduced to a set of differential equations - no matter how complex. It is more that I am searching for simple classes of systems in which some of the more salient features of culture and social process are apparent. It is unlikely that any theoretical model of cultural process can be complex and detailed enough to be deterministically predictive on a fine scale. My hope is that if I can begin to understand the dynamics and relevant parameters of a few simple systems, my understanding and appreciation of the real messy

world of the dynamics of culture and social structure will deepen.

## II. Culture and Social Transmission in Hominids and Non-Humans

> "Culture ... is that complex whole which includes knowledge, belief, art, morals, law custom, and any other capabilities and habits acquired by man as a member of society."
> -Sir Edward Burnett Tylor (*Primitive Culture*, 1871)

One of the things which initially prompted me to do research on information transmission and culture was the question of the relationship between genes and culture. I was in an evolution class and doing reading on dynamical systems at the same time. So the question wasn't so much the near cliché of Nature vs. Nurture, but more how the cultural and genetic influences might play out as a developmental system for generating an individual's phenotype. There seems to be an odd asymmetry in the evolutionary literature. The mathematical framework for describing the changes in population gene frequencies brought about by differential selection on organisms is very well developed. Many of the implications of the powerful concepts of genetic evolution and fitness lead to explanations of certain social phenomena which are both fascinating and persuasive (kin selection and altruism, for example). But it seems that in many evolutionary models surprisingly little attention is paid to the potential impact of cultural transmission in determining some aspects of the "behavioral phenotype."

There are many reasons for this, I'm sure. We now understand a great deal about the actual physical process of genetic transmission, and this makes it possible to calculate the statistical mechanics of genetics with some certainty. Although there has been a long tradition of cultural research in anthropology and the other social sciences, the models and metaphors employed do not always translate easily into mathematical terminology (and vice versa). Despite attempts at interesting "meme" analogies, and some philosophical musings on the

nature of replicating information in general[2], there is no understanding of what the fundamental units of culture might be. The challenge is to create descriptions of cultural process which are in a form which allows comparison and integration with genetic descriptions. The specific adaptive values of culture are poorly understood, and the fitness implications of bio-cultural transmission are only beginning to be examined. At this point humans are the only species which certainly include some amount of cultural transmission processes in the construction of behavioral phenotypes[3]. The uncertainty is due in part to considerable uncertainty about how culture should be defined in humans, let alone in a form general enough that it could be tested for in other organisms. But intuition, and some evidence, suggests that forms of information and behavioral transmission do exist in groups of other animals. Examination of these potential "proto-cultures" may help define the underlying ideas of culture and information transmission.

The study of animal behavior and learning is an old and extremely active research area. I cannot pretend to have more than a passing familiarity with the literature, but it seems possible that some of the phenomena of information transmission might not even require a clear ability to learn new behavior at the level of the individual. An alarm reaction in a school or herd, for example, could be an entirely programmed response, where the activation of the response might employ a crude form of social communication. A single individual may notice the presence of a predator and communicate this environmental discovery to others through a behavioral display. This behavior activation might spread through a group in an epidemic fashion, perhaps causing a mass evasive action in which all individuals, including those who never directly sensed the predator, will participate. (Smith, 1991) Clearly, information about the state of the world is being transmitted, even without the requirement of a sense of intentionality of the participants. Boehm (cited in King, 1991, p.100) presents a "...hierarchy

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[2] Richard Dawkin's *The Selfish Gene* (1979) has an extensive discussion of the "meme" concept. Also, see Lumdson and Wilson's *Genes, Mind, and Culture.* (1981)

[3] This is somewhat of a tautology, as definitions of culture often boil down to "whatever it is that humans do that animals don't". But for an extensive listing of papers documenting the existence of vertical (p.50) and horizontal (p.54) cultural transmission in humans, see Boyd and Richerson (1985).

of communication intentionality" "... suggest[ing] that an animal might: (1) advertise emotional states only; (2) communicate information about its social and physical environments; (3) intend to communicate so that the information transmitted has an effect upon the hearer; or (4) communicate intentionally in matters that involve displacement in time or space."

But how should the role of individual learning be viewed in the process of cultural transmission? Organisms may live in a group, but if individuals are able to learn to make distinctions about environmental states without the assistance of interaction with other members, cultural transmission may not be required for the acquisition of behavior. Still, the presence of conspecifics may help facilitate the process through socially mediated learning. Laland and Williams (1997) describe a series of laboratory experiments in which schools of fish are trained to locate a food source. When "naive" fish are introduced, they follow the school of demonstrators to the food. The location of the food is "remembered" by the fish (or perhaps the school) even when all of the original fish have been replaced. "The results suggest that the tendency to shoal may facilitate a simple form of guided social learning, which allows guppies to learn about their local environments. They also imply that selectively neutral behavioral alternatives may be maintained as traditions in aggregated animal populations by very simple social mechanisms." (p. 1161) This is a case which certainly doesn't require any intentionality, and in which there is no abstract communicative process; yet it is consistent with some definitions of transmission: "...social transmission ... occurs when a social interaction increases the likelihood that one individual will exhibit a behavior initially the repertoire of another." (King 1991, p. 99, from Galef)

I think that the guppy example emphasizes the need to distinguish between the transmission of information and the transmission of culture. I will save a discussion of the nature of information for later, but I think that Galef's statement provides a good working definition of low-level social *information transmission*. A good definition of cultural transmission might require the inclusion of a clear description of the kinds of learning and the time frame to be considered. I'm going to define *cultural transmission* as occurring when a

behavior initially in the repertoire of one individual appears in the repertoire of another, but only when the second individual also gains the ability to re-display the behavior at points in time and space which are appropriate but distinct from the original setting. For a setting to be considered "appropriate," it would probably have to preserve an association with some of the perceptual and contextual elements of the initial situation. Two further examples point out some of the complexities in trying to arrive at any kind of working definition of culture or cultural transmission.

MIT's StarLogo[4] website presents a model which simulates the synchronization of firefly flashing. The model is a translation into computer code of a simplified description of the flashing behavior of one firefly, and a set of rules for how each of the single firefly "agents" will interact with its neighbors. Although it is not clear that the model presented in the simulation reflects the actual process as it occurs in real fireflies, the dynamics of the simulated flies are qualitatively similar to what is observed in nature. (Buck 1988)

> In the region from India east to the Philippines and New Guinea, enormous aggregations of fireflies gather in trees and flash in near-perfect synchrony. While different species have slightly different methods for flashing in rhythm, the behavior that is modeled here is governed by the following rules:
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> - Each firefly has an intrinsic flashing frequency, and when left alone it will flash at periodic intervals.
>
> - The flashes are timed by the progressive excitation of a chemical within each firefly; the excitation increases until it reaches a certain threshold, at which point a flash is emitted and the excitation is reset to zero.
>
> - If a firefly senses a certain amount of luminescence from its neighbors, it will reset its excitation to zero in order to flash simultaneously with those neighbors in the future; however, if the excitation is close enough to the flashing threshold, the flash has already been started and will proceed as planned even though the excitation is reset to zero. (The signal to flash is initiated when the excitation is 80% of the way to the threshold value.)

[4] StarLogo is an agent-based simulation environment developed for educational purposes. The software and this example can be located at: http://www.media.mit.edu/starlogo/

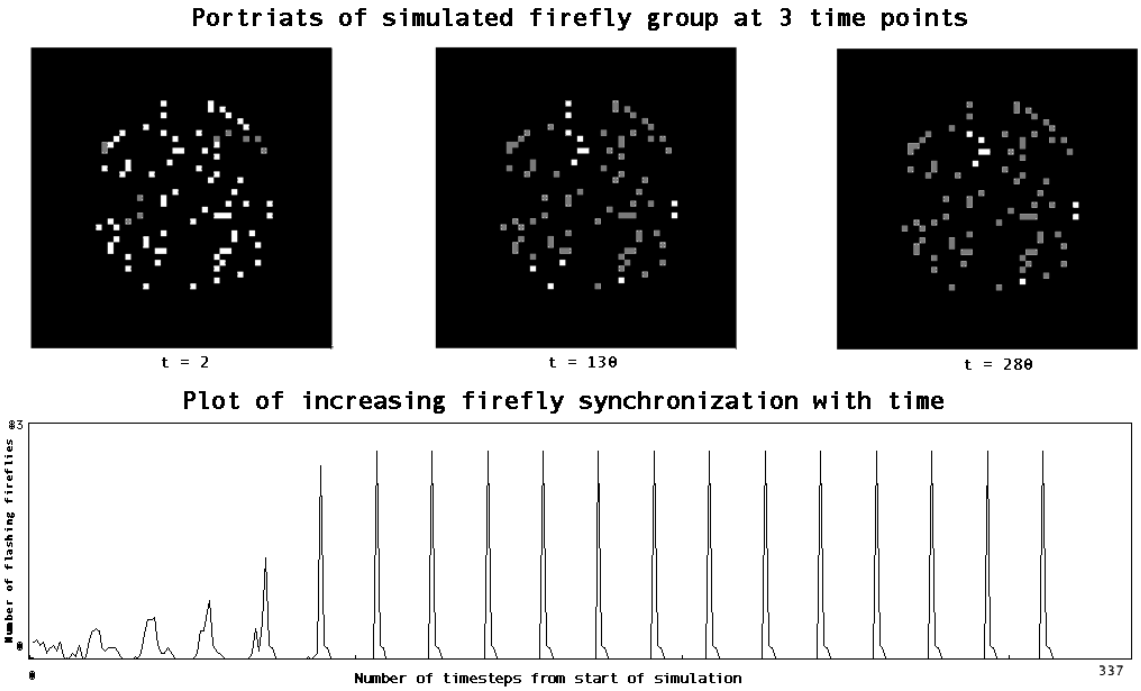


Fig. 2 Screen shots and time series from StarLogo simulation of firefly flashing behavior. In the top panels, gray squares indicate flashing fireflies, white squares dormant fireflies. Time series shows the number of fireflies "on" at each time step. Notice the increasing synchronization - development of large spikes with almost no tails. (code from StarLogo web site 2001, slight modifications by author to produce time series.)

Obviously real fireflies do many more interesting and complex things than this model allows. But the important point is that the model demonstrates concretely the formal potential for coordination - the emergence of a specific form of synchronized group signaling - among a large number of individual "agents" relying only on very simple rules and with no central coordinating authority. The only form of communication taking place among the simulated agents is a simple on/off message which can only be received by the few agents in the immediate vicinity. This a good example of the type of phenomenon investigated by complexity theory. The synchronized flashing of the group is considered an "emergent" behavior because, although it is definitely a result of the interaction rules given to the agents, it is not explicitly described in the rules. Furthermore, it is a property of the system that is scale-dependent - it doesn't have any meaning and could not be discovered by examining the behavior of one firefly in isolation. Although it would be quite a stretch to class the firefly

example as a cultural phenomenon, there is clear evidence of information transmission, (increasing display of identical flashing frequency) and even of a type of aggregation or consensus formation. The consensus achieved in this model is qualitatively unlike "issue" consensus in humans, because the message is discrete and the range of transmission increases as each of the sub-groups synchronize into bright regions. But it is interesting to think about comparing the firefly model to some instance of human behavior - synchronized clapping behavior in concert crowds for example. (Fountain, 2000)

Another classic case concerns the reports of British birds opening milk bottles. Apparently, sometime in the late '40s, Blue tits began pecking through the foil tops of milk bottles to drink the cream. In his brief discussion, Bonner (1980) implies that the innovation appeared in a single location and the skill spread all over the British Isles through a process of epidemic imitation and cultural diffusion. However, even the paper he cites (Hind & Fisher, 1951) offers a more cautious interpretation: the apparent cultural transmission may be better described as a socially facilitated learning process of "local enhancement." Although the distinction may seem fairly arbitrary, the implications are interesting. If the birds learn the behavior though a local stimulus enhancement phenomenon, there is much greater potential for birds to make the discovery independently. "Sherry and Galef's results, for example, showed that experience with previously opened bottles was sufficient to establish milk bottle opening in birds that do not spontaneously exhibit the behavior" (Nicol, 1995, p 83)

In a sense, in the case of the Blue Tits the distinction between imitation and stimulus enhancement learning is not important - behavior is still moving from one repertoire to another, and the behavior still spreads whether from one genius bird or several. But clearly there may be situations where the distinction is essential - when birds are kidnapped to a behavioral laboratory and must learn arbitrary new tasks to obtain food, for example. Nicol gives a good description of imitation:

> ... the observer may be able to copy the exact motor patterns of the demonstrator by some (as yet unknown) process of cross-modal matching.

as distinct from stimulus enhancement:

> ... the behavior of the demonstrator may result in an increase in the salience of a particular stimulus or location within an overall environment for the observer. The observer's attention may be drawn towards previously irrelevant features, or the observer's motivation to investigate the stimulation or location may be increased. (Nicol, 1995, p. 83)

One way to think about this is to imagine what kind of meaning content would need to be conveyed in each of the suggested possibilities. In the case of socially mediated stimulus enhancement, there is a sense of information as discrete incidence, a releaser of innate action: "this bright object is food, exhibit appropriate behavior." (The firefly and alarm-reaction examples would fit into this class.) Imitation would seem to require the transmission and reception of information of a more narrative or descriptive kind: "this is a sequence of behaviors which you can use to get food from an unusual source." It is not clear that either process would be in any sense less complex than the other. And, as Nicol points out, "... stimulus enhancement followed by trial and error learning may be a more efficient way of acquiring a skill in many circumstances." (p. 84) Part of what is confusing here is that when considering "lower" animals, imitation would seem to be the more complex task - perhaps requiring the abstract concept of the Other as similar to the Self.[5] In humans, where the ability to abstract is fairly strong, intentional communication via stimulus enhancement is arguably one of the highest forms of communicative cultural behavior, and imitation is viewed as a relatively mindless task.[6] I believe that the root of the confusion lies with the automatic attribution of intentionality and the capability for abstraction which we, as humans, naturally give to descriptions of other humans.

The distinction between the processes of transmission-by -stimulus-enhancement and transmission-by-imitation becomes crucial if we are concerned with what happens when errors, mistakes, or misinterpretations occur between the communicators. The results of a chain of

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[5] For an excellent discussion and further results of social learning and behavioral transmission in animals, see Zentall and Galef's *Social Learning* (1988).

[6] It is interesting to contrast the "bulimic" model of education, (cram the students full of facts with the requirement that they spit them out undigested on a test) with the learning process as facilitated by a good teacher (set up the environment so that the conclusion will become evident and let the students figure it out for

transmission events could be very different if the message is singular as opposed to being constructed from continuous or multi-part items. In the multi-part case there is the potential for behavior patterns to "drift" - errors can be additive in a way which is impossible in the singular case. One way of thinking about this is to refer again to the Blue Tit example. There are several ways of describing the communicative process which occurs when one bird observes another opening a bottle and obtaining food. Imagine that the message received by the observer is a singular one: it only needs to reclassify the milk bottle from "objects which are not food" to "objects which are food" The observer must rely on previously learned or genetically programmed behavior to determine the actions appropriate for getting food from a bottle. Errors in the message might result in the bird attempting to mate with the bottle, but if the bird tries to get food, it will always utilize the same patterns of behavior. If the patterns are genetically determined, they may be fairly uniform across a population, and changes must take place over evolutionary time through selection.

If the process is one of imitation and learning in which a complex series of motor skills must be correctly perceived and emulated, there are many opportunities for errors to disrupt the acquisition of the behavior so that it cannot be successfully utilized. However, there is also the possibility that a misperception on the part of the observer will result in a behavior which is *more* effective in obtaining food than the one he observed - perhaps using claws rather than beak to remove the foil. In other words, if the message consists of a collection of units or a continuous variable rather than a single programmed stimulus, there is the potential for errors or individual innovation to create many differing versions of a behavior. The stability of a predetermined behavior pattern is exchanged for flexibility. Although there may certainly be interesting fitness implications (in the standard biological sense) for birds which have different variants of a particular transmitted or learned behavior, at the moment I'm mostly concerned with differential selection at the level of the behavior pattern or message itself, rather than on bird reproduction. By allowing errors in learning, the potential may exist for

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themselves in their own way).

differential selection of behavior patterns on a time scale shorter than an individual's life span.

I'm aware that it is a questionable jump to begin applying selectionist terminology to a cultural process, but I believe that in this case it is justified. That is, we could make the not-too-unreasonable assumption that birds who aren't able to open bottles will stop attempting to use unsuccessful behavior. Alternatively, if the observers do not "see" a reasonable reward obtained, they may not try to copy the bottle-attacking behavior of the demonstrator birds. Or in the strongest case, they may evaluate the effectiveness of their neighbor's strategies and adopt the best. Either way, some variations of the behavior might increase in frequency in the population at the expense of others. This hypothetical example has many problems[7], and would of course be highly behavior-, animal-, and environment-specific. Over time, differential transmission of behavioral techniques could conceivably lead to the discovery and diffusion of very effective and/or very locally adaptive behaviors in a population. If there was any degree of restriction of the "mixing" or diffusion of traits through the population, subgroups which employ different behaviors to accomplish the same task might form. If the behaviors in question were involved with mate choice or courting, there might be effects at the genetic level. Needless to say, the interactions with biological fitness in its classical definition would be complex and difficult to predict intuitively.

Although the cultural components of heredity and behavioral transmission are not as well researched as the genetic component, it is a relatively rich and growing field. I would argue that debates about the nature of the cultural learning and transmission process do not necessarily reduce the usefulness of discussion or qualitative examination in the absence of hard data. But it is essential to remain clear that any conclusions about the dynamics of a message or behavior at a population level will generally be conditional upon the as-yet-uncertain formal properties of the transmission media and message process.

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[7] One of the problems is that Blue Tits may not actually imitate - although urban pigeons seem to. See Lefebvre and Palameta (1988).

## III. Adaptation and Models of Cultural Transmission

One of the crucial tools of modern evolutionary thinking is the notion that it is not only necessary to think about how a particular trait or relationship might be beneficial to its holder now, but also what circumstances were required for it to have become an adaptive variation in the first place. It is also essential to consider what structural factors must remain present to keep a trait from being removed from a population - is the behavior an evolutionarily stable strategy, or one which is subject to invasion by more "exploitive" traits? In this context, then, what are the biological-fitness enhancing values of "proto-culture" or communication which might have encouraged its emergence in early humans? Clearly this question is closely related to, and dependent upon, the adaptive value of cognition, consciousness, and communication. Is the continued existence of cultural behaviors which seem biologically maladaptive simply an unavoidable consequence of having big brains and jabbering mouths? Or are there group selection benefits? Are cultural behaviors subject to the same constraints of biological fitness, or do they reside in some other selective regime?

It might be useful to distinguish between discussions of (1) the adaptiveness and history of the evolution of culture and information transmission, (2) how evolutionary forces might act to generate or explain specific instances of culture, (3) social- or culturally-based forces which might drive dynamic "evolution" of culture, and (4) the effects of cultural transmission on biological evolution. Although they are all interrelated, and hopefully addressable by comprehensive models, they are often treated as distant fields that happen to have overlapping terminology. Some anthropological or historically oriented perspectives work to explain the events and dynamics of culture in traditional human or psychological terms but seem to lack the ability to generalize or make strong connections to other fields. Radical meme-

theorists often extend Richard Dawkin's concept of an informational replicator to the point where all human behavior is controlled by self-replicating concepts, all trying to out-reproduce each other by spreading to as many individuals as possible. This stands in stark contrast to the conservative biological approach which suggests that any influences of cultural transmission are slight, and must always be subservient to rules of hard-coded biologically adaptive behavior. I'm interested in perspectives which are integrative - meaning that they are extensible and explanatory on multiple scales. Especially attractive are models which are capable of coping with the very high speed (orders of magnitude more rapid than generation turnover) changes in "superficial" cultural traits and information, as well as providing insight about longer term trends.

The tricky part is that to evaluate any hypothesis for the adaptive value of culture, a model with very specific mathematical properties must be defined. There are many plausible models, each implying a different adaptive argument and possessing different dynamical properties. Distinguishing among the models will require a great deal of empirical data, most of which have yet to be collected. And there is probably a limit to how far it is worth pushing the models - the intent should be more to explain patterns than specific instances.

> We can easily explain by a sociobiological hypothesis why humans have symbolic capacities for culture. The main adaptive functions include interpersonal communication and memory organization. Both of these functions contribute to more efficient social learning and hence to more effective use of the various advantages of cultural transmission. However, since these functions are served equally well by any well organized symbolic system, we cannot explain much of the difference between the structures of different cultural systems by adaptive arguments. Language is the prototypical case: Chinese is not an adaptation to life on the Yellow River Plain, nor is English an adaptation to living in the British Isles, except in the very limited sense that its is useful to speak the language that happens to be common in a given place. (Boyd & Richerson 1985, p. 274)

Robert Boyd and Peter Richerson have done some work on integrating mathematical descriptions of cultural and biological transmission. They define culture "...as the information affecting phenotype acquired by individuals by imitation or teaching" - although they mostly restrict their analysis to a consideration of effects on the time scale of generations. Their book provides quite a few adaptive explanations for culture.

> In evolving a reliance on cultural transmission the human species may well have 'traded' high rates of random error caused by individual learning in variable environments for a lower rate of systemic error (with respect to genetic fitness) due to the partial autonomy of cultural evolution. (Boyd & Richerson 1985, p. 289)

Essentially, the argument is that if individual experimentation is "costly", it might be better to just adopt the behavior of successful group members. If the environment is sufficiently variable in time or patchy in space, it might be beneficial for groups to be able to adapt or adopt new behaviors more quickly than biological evolution would easily allow. In addition to allowing rapid change, the plasticity of cultural evolution may act to increase the diversity - the raw material for adaptive change - of strategies which are present in a population. In a set of computer simulations of evolutionary games, Findlay, Hansell and Lumsden (1988) showed that in their model "...biocultural games show a greater diversity of dynamical behaviors than their purely biological counterparts, including multiple fully polymorphic equilibria...biocultural games on average show greater equilibrium strategy diversity. These results suggest that cultural transmission in the presence of natural selection may be an important mechanism maintaining behavioral diversity in natural populations" (p. 245). To put it another way, models which allowed strategies to be transmitted both culturally and genetically displayed more attractors - bio-culturally stable strategy mixtures for the population to explore, than models of biological evolution alone.

It is also important to realize that for social creatures like humans a large part of the environment which determines their fitness consists of other humans. Survival may at times depend on an ability to coordinate with others for various kinds of collective action. So the adaptive environment in which cultural traits are "evaluated" will consist partially of the traits of other individuals. Findlay, Hansell and Lumsden (1988) refer to the concept of bio-cultural fitness, using it as a framework for thinking about the combined effects of genes and culture on the fitness of a behavioral phenotype. In organisms that have culture, the two types of fitness may be coupled because once cultural systems have evolved, the potential biological impacts of failing to adopt local cultural traits could be large. It is easy to think of situations where an individual's ability to procure resources or a mate might be impaired if they speak a

different language or follow a different system of courtship. "Cultural traits which affect mating preference could similarly affect genetic evolution through the action of sexual selection." In a sense, "the human genome could be 'domesticated' by culturally transmitted traits" (Boyd & Richerson, 1985, p. 277). These effects may not be unique to humans. A study of mate choice copying in guppies gives "...strong evidence for the role of non-genetic factors in sexual selection and underlines the need for new models of sexual selection that explicitly incorporate both genetic and cultural aspects of mate choice" (Dugatkin & Godin 1992, p. 179).

As I began to suggest in the previous section, the possession of cultural properties might make it necessary to revitalize some limited group selection arguments. Culture makes possible a certain degree of "fitness sharing" across individuals in a group and, as much as groups are homogeneous in their cultural traits, some degree of competition between genetically equivalent groups. Imagine, for example, the relations between groups which emphasize "pacifistic" and "warlike" ideals. Again, the outcomes can be highly complex and unintutive (there may be many situations where a collectivist pacifist society without "mean" neighbors does the best), and it is important to be highly cautions about drawing sociological conclusions. My purpose is simply to point out reasons that the inclusion of cultural transmission and other "humanistic" information effects is both necessary and helpful. Humans also possess many other properties which are interesting from an information perspective and may be pre- or co-requisites of cultural adaptation: strong language, abstract reasoning, symbolic skills, deception, intentional communication, etc.

> ... During hominid evolution, information could have been transmitted through leisure-time social interaction, vocal communication, material culture such as tools and art, and later, speech. Thus although differences in active information transfer, like the ones involved in symbolic communication, are undoubtedly quantitative, a truly significant product of human evolution is the ability and tendency to engage in active information transfer of all kinds. (King, 1991, p. 98)

Models expressing the properties of cultural transmission in humans must be capable of allowing for effects of intentionality and rationality in action and communication. That is not to say that people are always (or even frequently) rational in their behavior, but that they are capable of figuring out the "rules of the game" and exploiting them to their own ends. In many

cases this does not actually conflict with adaptive arguments: over time the processes of evolution can be nearly as creative about testing limits as individuals are, so strategies which are evolutionarily stable are usually not susceptible to "cheaters." However, individuals are capable of making decisions (and convincing others to abide by them) which are not easily explained with a simplistic adaptive argument - becoming a celibate monastic hermit for example, or fighting and dying for an abstract cause.

In a very real sense, all of these models and hypotheses, no matter how reasonable or well thought out, are "just so stories." Each has a set of sometimes hidden assumptions which must be justified before the predictions will hold true. One assumption which, although it is not unreasonable, is a requirement of many models of cultural change, is that traits are discrete. They do not always need to be discrete in the sense of having only integer values, but in the sense that when an individual is exposed to trait A and a variant A', one or the other is adopted rather than a combination of both. This is related to the property of heritability which is a requirement for evolutionary processes. Most of the models which are based on blending inheritance lose the capability for the gradual incremental drift which is the essential raw material for evolution by selective processes. This brings forward again the question of the scale and nature of the "fundamental units" of culture and information. This is a recurring theme - along with the discrete vs. continuous trait debate. Part of the reason it is so difficult to apply evolutionary logic to social and cultural phenomena is that it simply isn't clear what the nature of the substrate is - how similar the properties are to those of DNA substrate for encoding genes. Even when solid numbers on sociological variables can be obtained, the discrete nature of the data can be an artifact of the measurement instrument. For example, voting records and political party affiliation could be treated as an indicator of political alignment, but they are probably discretized measurements of the continuous and dynamic collection of variables which describe an individual's political perspective.

The model Boyd and Richerson (1985) develop is presented in several steps. They first consider the effects of "vertical" transmission, or adoption of traits displayed by biological parents. This is strongly analogous to biological transmission. They then consider "oblique" transmission - adoption of traits displayed by other mature models of the parents' generation. And then they briefly consider "horizontal" or peer-peer adoption. As I already mentioned, most of their models consider relatively slow moving heritable traits like language or religious affiliation. I have not examined the models of horizontal transmission in enough detail to know whether they could describe the fast transmission necessary for a description of gossip or institutional structure. The results of the analytical solutions of Boyd and Richerson's models of various bias effects on traits are fascinating. In this context, bias refers to systematic misperception or filtering effects triggered by some kind of perceptual cue. This will be discussed further in the section on human communicative processes. Bias is a useful concept because its effects do not need to be

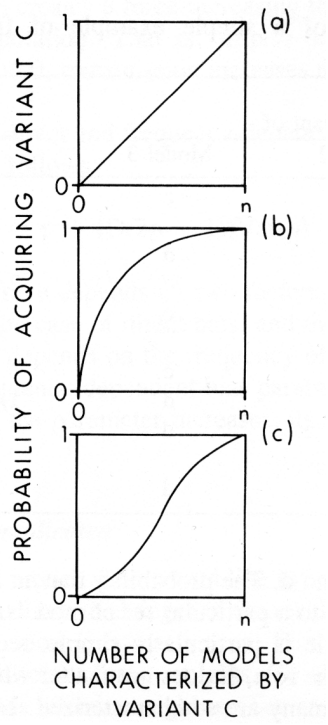


Fig. 3 Graphs indicate theoretical probability of a "naive" individual acquiring a cultural variant as a function of the frequency of the variant among the individuals potential models, assuming: (a) unbiased transmission, (b) directly biased transmission, and (c) frequency dependent biased transmission. (copied without permission form Boyd & Richerson 1985, p. 207)

deterministic. A bias is simply a predictable tendency, a nudge in a particular direction. There is plenty of room for noise and free-choice in a bias model, as the idea is that although the effects are due to processes occurring in each individual, they may only be detectable as a trend in a population or aggregate measure - a deviation from what might have been expected.

Boyd and Richerson describe three main bias effects which would impact the expected dynamics of cultural process (Figure 3):

> (1) Direct biases exercised by evaluating the traits to be adopted by their own properties.
> (2) Frequency dependent bias in which commonness or rarity of traits is used as the criteria for adoption.
> (3) Indirect biases which result from choosing models based on index traits, after which other traits are imitated without further evaluation. (p. 284)

Indirect biases especially allowed for strong "peacock's tail" effects - situations in which biological selection feedback causes arbitrary traits which are originally used as indicators of fitness in sexual selection to "run away" to values which are sometimes ridiculously non adaptive. "If we are correct, the forces of guided variation and direct bias are often weak enough to lead to substantial cultural variation, and therefore [biological] natural selection will be an important force acting to change the frequency of different cultural variants" (Boyd & Richerson, 1985, p. 285).

It is frequently the case that arguments from biological natural selection are used to explain changes at the cultural level. But, despite the fact that I've spent a great deal of space discussing the potential impacts of culture on biology, biological fitness may not be the best place to look for explanations cultural changes. It is possible that in some instances cultural and genetic transmission are largely decoupled. The current properties of culture may be such that many of the traits are effectively neutral with respect to biological fitness or are able to overpower the bio-fitness constraints because of runaway processes like indirect bias. In this scenario the cultural fitness of a trait need no longer be related to the lifetime fitness of the individuals possessing it. In fact, the reproductive fitness would seem to be a poor indicator of cultural fitness for fast moving traits. In other words, it may be possible for culture, especially symbolic culture which is already fairly arbitrary, to evolve and follow a selective regime

which is not necessarily congruent with the biological one. Traits could have a fitness in the sense of differential reproduction, measured by how many individuals adopt them in successive points in time. Unknown parameters could be acting to drive selection for various cultural or informational traits in the same way in which selective functions applied to the computerized worlds of genetic algorithms[8] result in "evolutionary" change. The strongest version of this would be meme based theory, but the principle can still hold in the more palatable sense of human biologically influenced intentionality and unconscious choice, developed over evolutionary time, as the selective force on cultural properties. In other words, there could be biological selection for various cognitive structures which then become the selective "environment" in which cultural properties are tested.

To me, a useful way to view the relationship between cultural and biological selection is with the metaphor of co-evolution. In the same way that two interdependent species act to deform each other's fitness landscape through an ongoing arms-race of co-evolved traits, biological and cultural phenotypes could exist in different selective regimes, but still be coupled to each other through each individual's actions so that all of its behavior is affected by both regimes. A phenotypic trait can have values in both the cultural and biological domains. Some behaviors or traits will be selected for in one regime and be neutral in the other. In some cases culture may reinforce the biological selective pressures, and in others conflict with it, the resolution eventually occuring through drift in other trait dimensions.

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[8] Designed "un-natural" selection procedures, which share some of the formal properties of genetical evolution but not its molecular substrate, have proved to be very useful for solving certain kinds of problems that require searching a large collection of potential solutions for the few which are effective. The kinds of solutions which result, and the speed with which they are located, have been shown to be highly dependent on the specifics of how the problems and solutions are encoded, and how the selective force is defined as a "fitness function". See Melanie Mitchell's *An Introduction to Genetic Algorithms* (1996) MIT Press.

One model for which the discrete/continuous distinction may be less important is that of culture as a process of innovation diffusion. The idea is that an innovation or idea occurs in one location and diffuses spatially through a population in time as if it were a biological epidemic or a chemical dye in a medium (as in the Blue Tit example). The concept is useful in that it allows aggregation of all the variables of individual choice and action so that the process of transmission can be viewed as a probabilistic "random walk" or percolation of a trait through the population - an area of mathematics which is fairly well understood. Some, especially historical processes, appear to be well described by such a model, although diffusionist perspectives seem to be currently out of favor in anthropology. The archeological record seems to show Neolithic agricultural practices spreading through Europe in such a fashion. (Cavalli-Sforza, Menozzi, & Piazza, 1994, See Figure 4) Although the diffusion concept may be a good metaphor on some (very large) length and time scales, it seems to lack many of the qualitative features of culture as it is currently experienced. Certainly there are very strong spatial effects on some traits, (language, regional dialects, accents, etc.), but as contacts between people become increasingly de-spatialized through the use of travel and

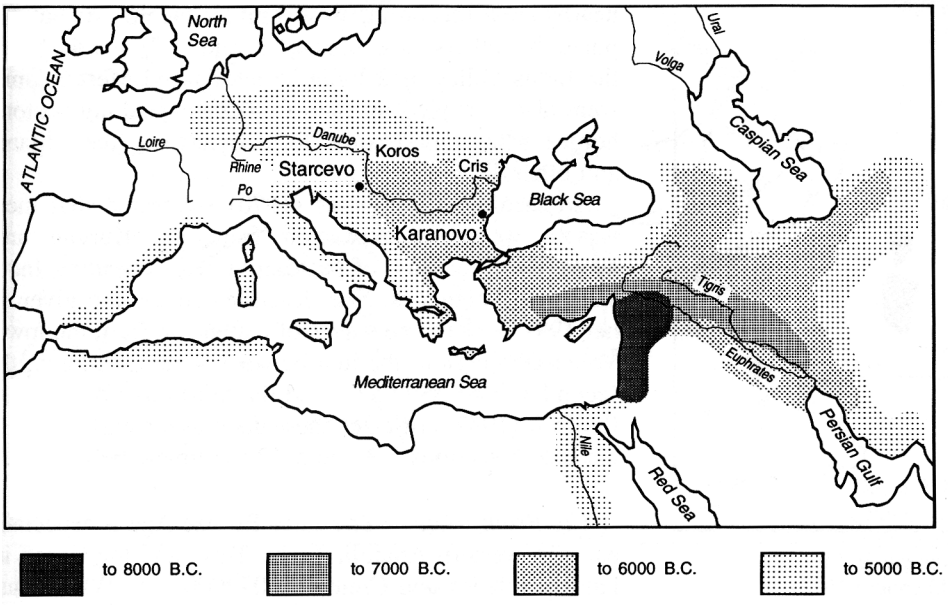



Fig. 4 Map of the spread of Neolithic farming cultures from the Fertile Crescent. Shading indicates presence of archeological indicators associated with agriculture for given time period. (copied without permission from Cavalli-Sforza, Menozzi, and Piazza 1994 p. 257)

electronic media, it becomes difficult to imagine the dimensions on which diffusion could be observed. Furthermore, diffusion concepts would seem to ignore the potentially powerful effects of social structure: long distance contacts, local friendships, ghettoization, political affiliation, mass media, etc.

A solution might be to create a model capable of including the effects of structural biases introduced by the effects of social structure, while still allowing probabilistic descriptions and limited diffusion. To me an exciting possibility would be the integration of diffusion models with social network descriptions of contact between individuals and contact with their environment. Trait or information diffusion could be imagined as percolation along the ties between social actors with probabilities weighted by the frequency of contact between them. This would have the advantage of including Boyd and Richerson's (1988) concepts of vertical, horizontal, and oblique transmission in the more general description. In other words, transmission of traits from parents to offspring could be due to the strong tie (extremely high contact probabilities) between parents and their offspring during childhood - yet long-distance, peer-to-peer, and media effects could be included as well. This idea will be discussed further in the section on social networks.

I think that it is important to reemphasize the role of material culture in the transmission of information and cultural traits. Human-generated artifacts have the ability to carry information and should properly be considered alongside direct personal communication. This was alluded to in the quote from King. Art, architecture, artifacts, tools, weapons, and more recently, texts, recordings, and photos all have strong communicative potential and have a remarkable ability to cross space and time. Material resources and positions in social structure (wealth, class, education level) are often heritable and transmissible (Bowles & Gintis, 2001, Boyd & Richerson, 1985). And social structure will likely influence contact with the information embedded in material culture as well as the information carried by individuals. This means that artifact- or media-based transmission can also be described from a percolation-network perspective. This could be done either directly with descriptions of

specific contact, or by considering the correlated environment effects which might appear because of social network associations with individuals. In other words, increased contact with a friend will probably mean increased contact with the friend's media and material culture as well - both via second-hand effects and simple proximity. For example, I'm much more likely to attend a show with a theater-going friend, read the magazines in his bathroom, etc. One advantage of this perspective is that it essentially sidesteps the correlated environments problem of previous attempts at separating the developmental effects of genes and culture in hereditary behavior transmission - the environment *is* the culture. Clearly it is important to consider what the term information "means" in these contexts. Can its properties be described in a sense which is discrete and/or relevant to questions about social and material culture transmission?

**IV. Information, Uncertainty, and Meaning**

The field of "information theory" or "communications theory" has as its core concept the idea of the transmission of information as the "reduction of uncertainty" about possible states of the source. The definition is very mathematical and involves very specific concepts of "message," "encoding," and the characteristics of the channel of transmission. Even though the formalization is in very mechanistic communications theory terms, the idea of reduction of uncertainty is a powerful tool for describing many information and transmission related phenomena. But there are also other common-use conceptions of information which, at least on the surface, appear unrelated to the communications definition. We often speak of objects as "containing information," as if it were a kind of liquid which could be poured into a book-shaped container by the author and wrung out drop by drop as the reader pages through it. It may be that speaking of information as if it were a substance is simply a convenient short-hand

which makes it possible to avoid the headaches and convolutions necessary to describe information as a time-based communicative process. But it is also true that the classic (Shannon, 1948) definition could simply be too rigid to express the complex shifting semantic meaning systems employed by humans in the processes of perception and communication.

As I understand it, the formal equations of information theory apply to situations in which there is a "source" of information connected to a "receiver" by a "channel" of some finite capacity.

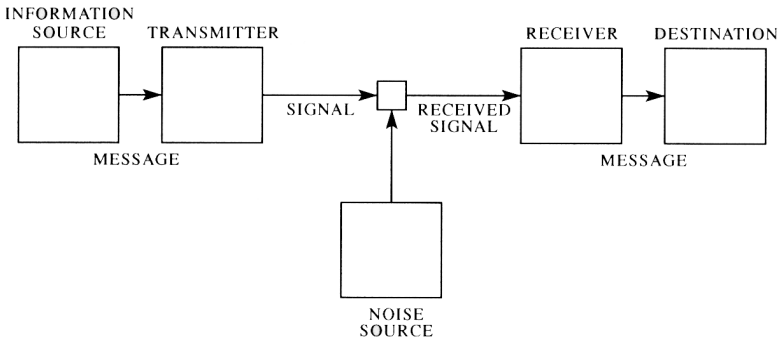



Fig. 5 Schematic diagram of a general communications system. (copied without permission from Shannon, 1948, p.2)

The idea is that the source can adopt any of a set of states and the receiver would like to know what state the source is in, but they are unable to perceive each other directly. If no message is transmitted over the channel, the receiver has no information about which state the source is in, and the receiver is in a state of complete uncertainty. If the source could send a message indicating its state, the receiver would know which of the potential states the source had taken, the uncertainty would drop to zero - information transmission would have occurred. The problem is that the state of the source must be expressed in a form which can be carried by the channel. This means that some sort of code must be established by which the receiver can make inferences about the state of the source by examining the state of the channel. It would perhaps be possible for the channel to have as many possible states as the source, but this would mean that the bandwidth or capacity of the channel would have to be tremendous, and the mutually agreed upon code would have to be as complex as the source. In human communication terms,

this would mean that there would have to be a symbol or signal for every single meaning that might ever need to be conveyed. However, if the source and receiver agree to consider channel states in groups over time, then the channel can be smaller and the code can be simpler. Rather than needing one channel state for each unique source state, unique groups of channel states from a smaller "alphabet" can be used, and the receiver can determine the state of the source according to the code.

But there are several trade-offs. Messages can no longer be transmitted instantly because time is required to space out the channel states in order to make the groups distinguishable. There is now the possibility of partial or incomplete messages, and the concept of information becomes more meaningful. Because each state of the channel only partially specifies the source's state, the receiver's uncertainty is only partially reduced. For example, the source could be trying to transmit an English word one character at time. Initially the receiver has no idea what the word will be. It could be anything in the dictionary, there is complete uncertainty, and no information has been transmitted. Suppose the first letter is sent is "r". Suddenly the entire dictionary of possible English words is reduced to only those which begin with "r". There are, of course, a rather large number of English words starting with r, but if the receiver picks one at random, the chances of it being the one the source intended are much better - the uncertainty has been reduced. The source can continue to spell out the word "r" "e" "c" "o" "r" "d" "  " one letter at a time. Each character has information "associated" with it because it further reduces the number of possible words from which the receiver has to pick. When the final space arrives, the receiver knows exactly which word was being sent.

I used an English word as an example because it immediately points out why it is difficult to directly apply information theory measures outside the realm of signals, compression, and communications technology. (I am, of course, doing great violence to the beauty and precision of Shannon's definition by recasting it in such vague terms.) The practical problem is that there are several definitions of "record" in the dictionary. It could be either a noun or a verb, and takes on several different meanings depending on its context. More

fundamentally, if the source and receiver are actually people trying to communicate, they will have no exact dictionary in common from which the number of potential states could be counted to calculate the uncertainty. In the real world, the definitions of source, channel, code, and receiver are difficult to pin down, seeming to change moment by moment depending on the context, question, and level of analysis. A book can be considered a source of a perceptual message, the channel for communication between the author and the reader, one element in the code of literary culture, and as a partial dictionary for the decoding of its own information.

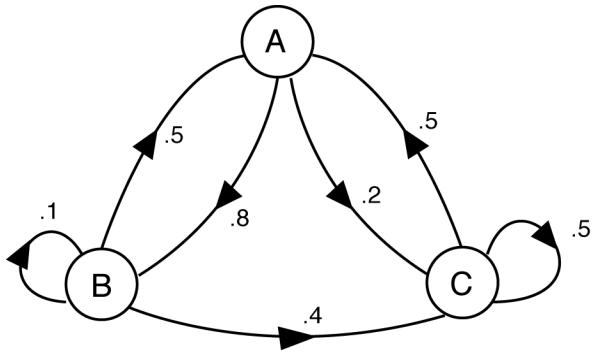
I think that the concept of reduction of uncertainty can serve as a powerful heuristic for thinking about information. But if we are going to extend the discussion beyond mechanistic communications theory to the diversity of processes involved in the transmission and perception of information between humans, we need much broader and perhaps less formal conception of information. As Umberto Eco states in his *A Theory of Semiotics :*

> Those who reduce semiotics to a theory of communicational acts cannot consider symptoms as signs, nor can they accept as signs any other human behavioral feature from which a receiver infers something about the situation of the sender even though the sender is unaware of sending something to somebody. (Eco 1976, p. 16)

In humans the process of coding, decoding, and pattern detection is amazingly flexible and versatile. We seem to be able to give any object, act, or event meaning and informational properties simply by changing our frame of reference and the context in which we are assembling meaning. The word "record", for example, now has an additional meaning. It can be used within the context of this text to reference a crude attempt to explain information theory.

Going back to the more formal source-channel-receiver model for a moment, it is interesting to consider the process by which a code could be agreed upon in the first place - how dictionaries are synchronized. Information theory often describes the properties of the source in terms of transition probabilities. That is, all states of the source may not be equally probable, and the chances of a certain state occurring may depend to some degree on the previous states. Essentially what this means is that there may often be a statistically detectable structure to the source's output. Structure here means that there may be frequency and grammatical properties of the messages which become apparent after enough time has passed or enough

messages have been collected for analysis. Even if the receiver knows nothing about the source, the number of potential states, or the coding rules, and must rely entirely on the channel for information, some predictions about the source will soon be possible.




Markov graph of transiton probabilites between states A, B and C

Fig. 6 Image of a simple Markov graph with three states. Each arrow and its associated number give the probability of the state transition in that direction. Notice that in this example, states C and B have probabilities of repeating, but an A could never be followed by another state A. (after Shannon 1948)

This is basically a crude description of a Markov process . (Figure 6) If the receiver keeps a careful count of the messages, it will eventually be possible to construct a table of transition probabilities for each of the states or characters. In other words, if the last character was "A", what are the odds that the next will be "C"? The idea is that if the source is not just generating noise, there should be detectable patterns to the messages. Some symbols may frequently occur together, (Q and U for example) where others rarely do (X and Z). To use an extended example from Shannon:

> To give a visual idea of how this series of processes approaches a language, typical sequences in the approximations to English have been constructed and are given below. In all cases we have assumed a 27-symbol "alphabet," the 26 letters and a space.
>
> 1. Zero-order approximation (symbols independent and equiprobable).
>
> XFOML RXKHRJFFJUJ ZLPWCFWKCYJ FFJEYVKCQSGHYD QPAAMKBZAACIBZLHJQD.
>
> 2. First-order approximation (symbols independent but with frequencies of English text).
>
> OCRO HLI RGWR NMIELWIS EU LL NBNESEBYA TH EEI ALHENHTTPA OOBTTVA NAH BRL.

3. Second-order approximation (digram structure as in English).

ON IE ANTSOUTINYS ARE T INCTORE ST BE S DEAMY ACHIN D ILONASIVE TUCOOWE AT TEASONARE FUSO TIZIN ANDY TOBE SEACE CTISBE.

4. Third-order approximation (trigram structure as in English).

IN NO IST LAT WHEY CRATICT FROURE BIRS GROCID PONDENOME OF DEMONSTURES OF THE REPTAGIN IS REGACTIONA OF CRE.

5. First-order word approximation. Rather than continue with tetragram, ...n-gram structure it is easier and better to jump at this point to word units. Here words are chosen independently but with their appropriate frequencies.

REPRESENTING AND SPEEDILY IS AN GOOD APT OR COME CAN DIFFERENT NATURAL HERE HE THE AN IN CAME THE TO OF TO EXPERT GRAY COME TO FURNISHES THE LINE MESSAGE HAD BE THESE.

6. Second-order word approximation. The word transition probabilities are correct but no further structure is included.

THE HEAD AND IN FRONTAL ATTACK ON AN ENGLISH WRITER THAT THE CHARACTER OF THIS POINT IS THEREFOR ANOTHER METHOD FOR THE LETTERS THAT THE TIME OF WHO EVER TOLD THE PROBLEM FOR AN UNEXPECTED. (Shannon, 1948, p. 7)

So after a certain amount of time spent observing messages, the receiver may be able to make fairly good predictions about what the next state of the source will be (assuming that the message represents the state of the source). This is interesting for several reasons. A fairly good measure of cumulative information transmission is possible using the perspective of information theory: as the receiver collects more messages, the predictions become more accurate, so the uncertainty is reduced. This means that messages which are "surprising" carry a great deal more information than those which are in line with previous experience.

> ...since information, subjectively, is measured by changes of probability estimates, what is perfectly predictable contains no information. Those sources in the physical environment which are time-independent and permanent, like buildings, streets and fixtures, after a time will cease to have information for the habitual user of the environment. (Benedikt 1975 p. 85)

For example, if the source has been sending out the text of Shannon's example 5, the receiver may be operating under the assumption that there are only 21 letters in the in the alphabet. When a word containing Q appears, the receiver will have to revise her assumptions about the number of possible states the source can take. And from a strictly formal standpoint, this may

alter the amount of information in previous and future messages because the value of the "change in uncertainty" used to measure information depends on the number of states the systems can take.

So there are several qualities of Shannon's conception of information which are consistent with a more pragmatic sense of the term. As much as there are patterns in the world, information about the past makes it possible to predict the future. The longer the messages, and the longer the time period of collection, the better the predictions are - more information is known about the source. Yet at the same time, it is possible for extremely short messages, ("Q") to carry a great deal of information and alter the relevance of previous and future messages. A single message can be the clue which induces a "re-framing" and re-analysis of previous data. In a sense this is the "flash of insight" in social situations when we suddenly reinterpret what we thought was going on or notice the implicit rules we have been playing by: "...one could then see...that the significance of certain deviant acts is that they undermine the intelligibility of everything else we had thought was going on around us." (Goffman, 1974, p. 5) There is also a sense in which information transfer allows the ability to perceive more states and make finer distinctions among states of the environments. It allows us to acquire increasingly detailed schemas or affordances for interpretation and action. "Knowledge of the environment surely develops as perception develops, extends as the observers travel, gets finer as they learn to scrutinize, gets longer as they apprehend more events, gets fuller as they see more objects, gets richer as they notice more affordances. Knowledge of this sort does not 'come from' anywhere; it is got by looking along with listening, feeling, smelling tasting." (Gibson, 1979, p. 253) That all these various aspects of information might be tightly interdependent is somehow not surprising. Yet clearly something changes when the level of analysis is raised to that of everyday communication and meaning.

Although it may be possible to construct crude models of human communication as a Markov-chain process of character frequencies or conversational states (Thomas, Roger & Bull, 1983) this does not seem to be the level at which humans typically obtain or utilize information

and meaning. We seem to be able to deal effectively with letter or word prediction on an unconscious level. This does not mean that we are incapable of dropping to a lower level of analysis if the context or task demands it. We may, for example, be able to locate a person's accent from a few deviations in vowel pronunciation, or spell check a document if required. But people almost always speak grammatically (at least according to their regional subgroup) and spelling is fairly consistent among literate people. (Myself being case out of point!). So an analysis of letter frequencies usually doesn't provide us with much information and we tend to gloss over the minutiae. We generally deal with larger units of words, sentence structure, and meaning.[9] And, of course, many of our sources of perceptual information cannot be as conveniently chopped up into discrete symbolic units for analysis the way written text can.

There are other approaches possible in a discussion of information. Unpacking the layered meanings and information associated with signs, communication, behavioral acts, perception is often considered the domain of Semiotics. Eco (1976) presents an interesting developing synthesis. His focus is on the attribution of meaning to, and the dynamics of the associations between, signs and symbols in communication. He describes the phenomenon of a symbol's meaning as occurring like a hierarchical chain of the various potential connotations. The meaning which a symbol or action takes at a certain place or time depends on the context of the instance and the depth of the viewer's analysis. He points out that contradictory readings of the same sign are often possible - or even co-present in a person's understanding. Signs often carry with them a sort of ontogenetic history in the form of ghost meanings which reveal themselves on analysis. His emphasis is definitely on meanings as aggregate and continuously changing items.

> Metz (1970) has advanced the hypothesis that in every case of communication (except for maybe some rare cases of a very elementary and unequivocal type) we are not dealing with a message but with a text. A text represents the results of the coexistence of many codes (or, at least many sub-codes). (Eco 1976, p. 57)

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[9] And we even group these into larger patterns. Consider, for example, the expression: "How are you?" and the almost obligatory response: "Fine." In most encounters the exchange reads as a greeting and the literal interpretation, an inquiry about a state of mind or health, is not responded to.

From his description, meaning seems like something sticky which gets attached to signs each time they are used. If a symbol or action is used in a consistent fashion by a large number of people for some time, there will be a fair amount of consensus as to what it means. But there is still the possibility of any individual giving a sign a new, "less ratified" meaning by using it in a different context with a different intent.

For information transfer to occur, there must be some form of material or energetic contact between communicators. This means that although information is probably not a visible entity in most transmission situations, the behaviors of the people who generate and receive it often are visible. Although the actions taken by individuals in the course of their daily lives may be almost incomprehensibly complex, it is at least possible to imagine crude ways to search for patterns and draw inferences about where information exchange is occurring. In fact, because I'm mostly interested in getting at the properties of information and culture in the context of groups of people, it seems fairly essential for me to look at how some of the structural properties of human relations and communication affect information transmission.

## V. Humans, Bias, and Communication Phenomena

Even if the specifics of the processes of coding meaning and information in intentional (or unintentional) communication are not fully understood, some of the results may be visible on a social level. If individuals have exchanged information, there might be a convergence in the meanings they associate with certain signs or actions. There my be an increased tendency to see things from each other's perspective. Through conversation they establish a common context, a dictionary of shared words, and a collection of common connotations and references which grows with each interaction. In Eco's terms, the "semantic trees" exchange elements; the possible meanings attached to the symbolic referents they employ become more similar. In a sense, a

micro-language is developed, a subculture between the interactants, a set of expectations and conventions. If it were possible to attach some metric to the degree of meaning convergence, this might be a usable measure of information transfer.

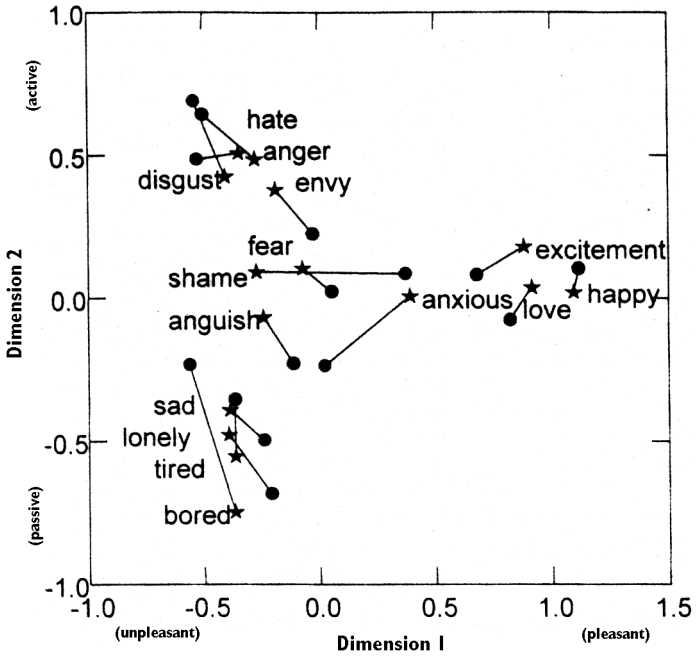


Fig. 7 Diagram shows a summary of differences in mean semantic loadings of terms for English (star) and Japanese (circle) speakers. In this spatial representation, emotion terms that are judged as more similar (by a method similar to Osgood's) are closer to each other than terms that are judged less similar. The dimensions of the diagram are from a Principal Component Analysis. Dimension 1 appears to correspond to what Osgood referred to as the Evaluative Factor (good-bad, pleasant-unpleasant, positive-negative) and Dimension 2 appears related to his Activity Factor (fast-slow, active-passive, excitable-calm). (copied without permission form Romney et. al. 1999)

Although not directed specifically towards information transfer, Charles Osgood's "semantic differential" (1952) has some useful and conceptually similar elements. Osgood developed a methodology for using sets of 7-point scales with polar terms to measure the meaning of particular concepts. (ex. PACIFIST: Kind <- - - - - - -> Cruel ) He reports that the evaluations were very consistent across subjects in several studies. When factor analysis was performed, there was a strong tendency for ratings to occur along a few underlying dimensions. In other words, a great deal of the variance could be explained by an "evaluative factor" along with a "strength factor," an "activity factor," and "several others not clearly defined in this rough approximation." (Osgood, 1952, p. 228). This suggests the possibility of representing the semantic associations of words by positioning the words as points in a multi-dimensional space so that the coordinates of the point give the factor loadings for the word. (Figure 7) As the connotations for the word and its usage change over time, repeated surveys might show gradual

change in the factor loadings, resulting in the point "drifting" over time as its general meaning changes. Osgood mentions a study by Stagner and Osgood in which:

> ... a set of scales was used to measure the 'meaning' of particular concepts, such as PACIFIST, RUSSIAN, DICTATOR, and NEUTRALITY. Successive samples of subjects were tested between April, 1940, and March, 1942 (including a sample obtained just prior to the Pearl Harbor incident). ... The feasibility and efficiency of using this method to record the changing structures of social stereotypes (e.g., the changing meanings of a set of social signs) were demonstrated. That a total shift from an essentially pacifistic to an essentially militaristic frame of reference had been accomplished, even before the Pearl Harbor incident provided the spark to overt expression, was clearly evident in the data. (Osgood, 1952, p. 226)

It seems likely that similar effects would be present at the level of individual interaction as well. Perhaps if two individuals were to take a semantic differential test on a specific subject, asked to discuss the subject with each other, and then re-tested, there might be some measurable convergence of the points representing the relevant concepts in their respective "meaning-spaces". The idea of "information transfer" in this kind of methodological and conceptual framework would be based more on changes in conceptual linkages and semantic loadings than on reduction of uncertainty.

Related to this is a research tradition resulting from a series of "serial transmission" experiments done by F.C. Bartlett in the 30's. The basic idea is that successive individuals in a transmission chain read a statement or story and then write what they remember as the input for the next person:

> In both Bartlett's original study and our serial reproduction phase, subjects assimilated the folk story with its unfamiliar ideas and obscure connections to their own culturally determined cognitive categories, or as Bartlett called them, Schemata. Bartlett's subjects and ours condensed, highlighted, and rationalized the story to enhance its apparent coherence and consistency. (Kurke, et. al. 1989, p. 15)

There are two lines of thought here which I think it is important to develop: Systematic transmission bias, and cognitive "schema" or "frames" as a tool for organizing informational input. As Kurke (and presumably Bartlett) implies, bias and framing are closely linked. It is interesting to consider schema not just as a filtering system for highlighting and assembling pertinent perceptual or meaning elements from an information stream, but also as a cultural unit

or information chunk itself. In other words, a different way of imagining the convergence and creation of shared meaning between interactants is to think of transmission as resulting in their possessing increasingly similar interpretive "frames". The process of creating a shared dictionary of meanings is in a sense a process of generating a common point-of-view from which to interpret the codes of communication. Individuals who possess the same schema will agree on what portions of raw perceptual data are relevant and which should be ignored or discarded.

The schema or frame is a good concept for describing the "meaning" sense of information transmission because the literature surrounding the term seems to be well aware of the potential for people to adopt new interpretive frames, to alternate between conflicting interpretations, and to refine or increase the detail and precision of the schemas they employ to make sense of their surroundings.

> ... the key modeling principle here is that a person's knowledge determines his ability to distinguish states of the world, and if a person cannot distinguish between several states of the world, he must take the same action in all of them. (Chwe, 1999, p. 2)

Transmission of a schema (or refinement of the detail in an existing one) need not be a permanent alteration to the perceiver's perceptual framework, and may not always result in convergence of the interactants' meanings. As individuals tend to discard or dis-attend information which is inconsistent with their current interpretation of what is going on, the schema they hold will likely affect the information they transmit. This is important for the filtering aspects. Losses and errors will not be random, instead they are likely to be strongly biased towards occurring in the parts of a message which are not understood or conflict with the teller's original perspective.

> [True white noise in a message] ...would appear to a later human unit as bizarre, imperfect, randomly distorted, and, beyond a certain degree of information loss, unintelligible But the output of the human transmission and memory unit, no matter what degree of information loss, is apt to *appear* to a latter human unit as intelligible and usable as a base of action. This appearance of plausibility and comprehensibility in the output can accompany a total loss of the input message. Human beings as transmission units have this characteristic of rationalizing, of filling gaps, of providing outputs that lead to action rather than paralysis. (Campell, 1958, p. 341)
> ... through anticipatory monitoring of his own intended output, he makes an active effort to produce a coherent output by suppressing remembered detail that does not now

> seem to fit and by confabulating detail when gaps are conspicuous. Transmission thus typically involves reconstruction. The less meaningful the material, the fewer notions the transmitter has about the appropriate characteristics of the output, the more machinelike and random will the error output appear. (Campell, 1958, p. 342)

Campell (1958) gives a good general overview and classification of the kinds of bias which occur frequently when humans engage in serial transmission tasks. Except for the last category, these biases occur at the level of the individuals in the chain and may or may not describe the results of the overall process.

1) Abbreviation, simplification, condensation and loss of detail.

2) Middle message loss.

3) Closure (tendency to complete according to a schema, make consistent.)

4) Tendency towards symmetry or "good figure". He points out that this is interesting from an information theory perspective, as regular or symmetrical forms have less information (can be described with fewer terms) than irregular forms of the same class.

5) Enhancement of contrast, figure/ground effects, categorization (things must be white OR black, not both)

6) Bias towards central tendency (ignoring unusual cases).

7) Assimilation to prior input (distortion to agree with previous information.)

8) Assimilation to expected message (hearing what one expects to hear.)

9) Assimilation to own attitudes.

10) Assimilation to reward and punishment: salience.

11) Distortion to please receiver.

12) Assimilation to prior output (desire to appear consistent to self and others).

13) Adaptation level, contrast error, or coding relativism (relativity of judgments to background and current context)

14) The tendency to make errors in output by duplicating input (failure to translate.)

15) Assimilation to prior coding assignments (holdover from other tasks.)

16) Coding contamination from associated cues (stereotyping, using one trait to

incorrectly infer the presence of others.)

17) Assimilation to evaluative coding (things must be good or bad rather than large or small.)

18) Misc. biases (population stereotypes, response bias, survey layout problems, etc.)

19) Over dependence upon single input sources (ignoring the larger picture or context.)

20) Assimilation to other channels.

21) Conformity, pseudo confirmation (effects of communication and consensus in groups - people agree with each other rather than with what they saw)

Like anything dealing with information and communication, the list is complex, somewhat arbitrary, and sometimes contradictory. Some of the categories seem most relevant to the specific laboratory experiments from which they were derived, where others are almost broad enough to be "laws" of communication - laws which will almost by definition have loopholes and outlying cases. How does one distinguish, for example, between messages which will be subject to "enhancement of contrast" (exaggeration of distinctions) and those which will be "biased towards a central tendency"? But Campell in no way claims to have done much more than scratch the surface of the categorizations and inferences which could be drawn at that date.[10] It is also important to consider the type of real world transmission tasks for which these categorizations are relevant. Campbell's review was done in part under the auspices of the Office of Naval Research. The idealized hierarchical serial communications chains of the military as corporate worlds which the survey pertained to may not be typical of the processes experienced by individuals in everyday life.

In fact, I would argue that most social information and communication phenomena we experience are not well described by a serial transmission metaphor. I do not by any sense mean that they will therefore be exempt from any of the biases. If anything, the process will be more

[10] It is interesting to compare these biases and their implications with the Boyd and Richerson's (1988) classes of cultural transmission bias. Part of the argument I'm trying to make is that cultural transmission may be communication "writ large."

complex and there may be more effects to account for. Campell was aware of this:

> In other settings, however, humans beings perform as groups, or operate as parallel units with interaction tangential to the stream of communication. In such situations it is possible that error tendencies arise in addition to those characteristics of single individuals. (Campell, 1958, p. 360)

As Campell suggests with his last category of conformity and pseudo-confirmation, one of the consistent findings in social psychology is that, not surprisingly, the decision and opinion formation processes of groups is usually not simply some kind of "sum" of the individuals' processes. Asch (1952), Sheriff (1936) and many others have repeatedly demonstrated that interactions between group members strongly affect individuals' statements about even seemingly basic perceptual judgments. It is not obvious how individual-level biases mentioned by Campell will affect system- or group-level dynamics when interactions are not delineated by the specific interaction geometries of a particular study.

Consider an experiment in the serial transmission tradition by F.L Brissey (1961). One group of subjects watched a short film (*Hit and Run Driver*) wrote a description, and took a relevancy weighted T/F test about its contents. The members of the second group each read a description from the first group, wrote their own description, and took the test. I'm simplifying the explanation, but basically data were collected on a set of 5-stage transmission chains. The basic results were not all that surprising:

> In all groups the information retained is of greater relevance than is either the misinformation or the lack of information." ... "In other words, in successive stages of serial reproduction, information of ever increasing importance is lost." [But] "A study of individual chains ... reveals pronounced variations from one to another. It appears that the accuracy and the completeness of a given chain is closely related to the effectiveness of given communicants. A relatively ineffective message midway though an otherwise excellent chain markedly and irreversibly curtails the content of the series. (Brissey, 1961, p. 215)

So most of the individual chains did not in fact follow the orderly loss curve of the group average shown in figure 8, and often had strong step-functions in them. This may not be that significant in a serial transmission setup, where each individual is allowed only one input - the average "quantitative" loss will still be the same. But if individuals are allowed the more natural role of integrative units assembling an interpretation from multiple sources, the

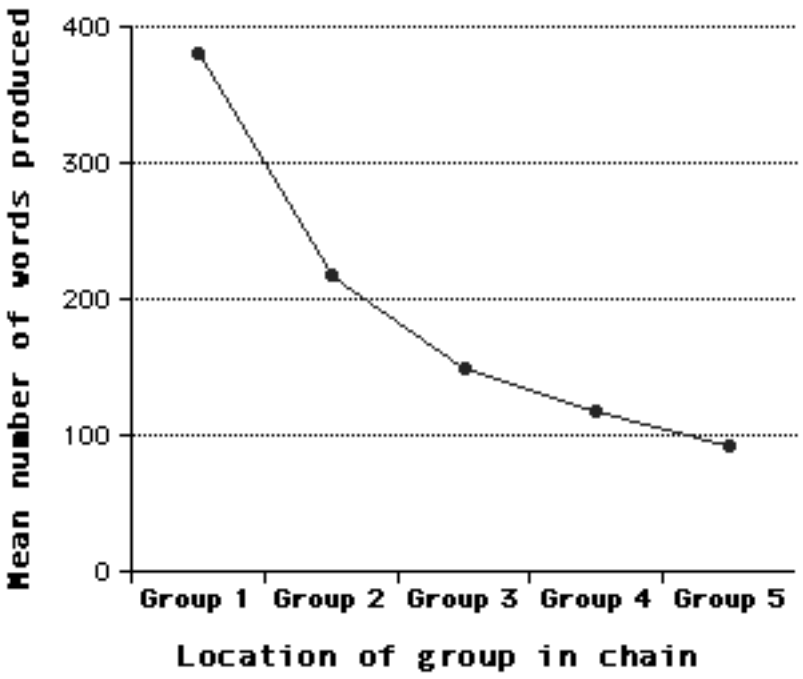


Fig. 8 Graph shows the relative amount of material (mean number of words) in descriptions produced by the participants at successive positions on the transmission chain in Brissey's serial reproduction study. (data from Brissey, 1961)

results could conceivably be very different. Imagine, for example, that all the individuals are connected together in a network so that each hears multiple versions of the story before repeating it. Even if several individuals have very bad communications skills and convey very little information, a person farther on "down" the chain may still get the full story from someone else. It is also important to consider that different people may lose different aspects of the story in their retelling. This means that there is the possibility that a person who receives several chains which contain very little information would still be able to re-assemble the story because each chain carried dissimilar items of the narrative. Of course, there is also the possibility of people assembling the incorrect or "bad" components of the story into a version which is equally self-consistent but very inaccurate - and it could be transmitted on down the chain instead.

Questions about the transmission of inaccurate information are often discussed in the literature on rumor transmission. Some early theories held that transmission would always lead to loss of details and "factual" information, but later work shows that the opposite is

often the case. Several studies emphasize the effects of rumor "importance" and situational "ambiguity," but often had mixed results. Ralph Rosnow (1991), in a short review of work on rumors, states that contemporary theory describes four main effects. More rumors are transmitted in experimental conditions in which subjects are very anxious, and there seem to be smaller effects due to credulity (believability of the rumor) and the "uncertainty" of the subjects. What is not clear is the relationship between rumor and information transmission in general. Do ambiguous or uncertain situations simply induce more communication attempts by the subjects, hence more transmission of accurate as well as inaccurate items? Are some situations particularly likely to cause errors and distortions? How good are people at sifting out the actual facts from garbled accounts? It seems likely that effects will be partially dependent on context, message content, connectivity, and numerous other variables.

To date, I have found little discussion or analytical work on the idea of people uninvolved in the original transmission re-assembling messages from partial information. Certainly it is a very real effect which should be taken into account in human communication processes. Although the problem is related to that of noise and error correction in a communication channel, it is also tied up in the cognitive abilities of humans as sense-makers. As I mentioned before, people have the ability to independently assemble similar interpretations, schemas, or concepts from the same data without any communication occurring between them. Or they may be able to pull together apparently disconnected information and events to intuit facts or relationships which have not been directly communicated. Even the absence of communication may provide information. This presents an additional challenge for any attempts to analyze short term studies in purely information theoretical terms - the base of common-sense knowledge employed by individuals to disambiguate events and messages is vast. Who's to say when a situation from a childhood detective novel will suggest an alternative interpretation of an experimental question? The order in which information is received may strongly affect how it is understood as well. People often seem to demonstrate a faithfulness to hard-won concepts and interpretations: "This tendency to distort messages in the direction of

identity with previous inputs is probably the most pervasive of the systematic biases" (Campbell 1958, p. 346)

There are also many different kinds of group level properties than can act to filter or bias the noise in transmission. Kurke, et. al. (1989), mention the concept of "uncertainty absorption" in organizations.

> When people absorb uncertainty, they often draw inferences from evidence 'using the categories of the organization's conventionally accepted conceptual scheme'." "... the more complex the data that are perceived and the less adequate the organization's language, the closer to the source of information will the uncertainty absorption take place. (March & Simon, 1958) [quoted in Kurke et. al. 1989 p. 6]
> ... serial reproduction removes information about beginnings, contingencies, and options and replaces it with information that suggests inevitability, givens, and certainty. (Kurke, Weick, Ravlin 1989, p.19)

In other words, there may be certain kinds of messages which a group simply does not want to hear. Individuals may feel implicit (or in political situations, explicit) pressure from the group to "soften their language".

As the statement is passed from person to person it may be softened out of existence or modified into a more desirable form.[11] This, again, brings up the issues of instrumentality and intentionality in transmission. Humans are often aware of some of the potential impacts of the information they transmit. There are certainly many specific situations which are not well described by a general bias as they are highly dependent on the content of the message. But even these instrumental situations (lying explicitly or by omission, controlling who is told what) may show some general trends when aggregated. In their study and literature review O'Reilly and Roberts (1974) mention fairly pervasive effects of status differences in hierarchies, and strong effects of trust on information communicated. Kurke et. al. (1989) mention in passing that females generally out-performed males in a serial transmission study.

Inherent in all these kinds of information transmission chain experiments are all sorts of interesting possibilities for methodological artifacts. This discussion began with the

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[11] Kurk, et. al. (1989, p. 4) give a fascinating and terrifying example of the behavior of US troops during the Vietnam War. "At My Lai...the order sent down from headquarters to a brigade said, 'On no occasion must hamlets be burned down.' The brigade radioed the battalion, "Do not burn down any hamlets unless you are absolutely convinced that the Viet Cong are in them.' The battalion radioed the infantry company, 'If you

assertion that there are as yet no established empirical techniques for quantitatively measuring information or its transmission. The problem certainly hasn't gone away. Word number counts and judged coding schemes (Kurke, et. al. ) or relevancy weighted T/F items (Brissey) are certainly a first step, but for all the reasons mentioned above, they are certainly not complete or appropriate measure for all situations. This is especially true when the media across which information transmission occurs is not spoken language or written text. The transfer of schemas or frames seems like a level of phenomena for which it is particularly difficult to define an appropriate metric. Yet this seems to be a conceptualization of information which is fairly in line with the way we commonly speak of it: as some "thing" which can be passed from person to person. At this level it might be more accurate to speak of what is being transmitted as an "idea" rather than "information" - although an idea (if it is a good one), provides an explanatory framework and so may fit well with the concept of "reduction of uncertainty" I'm beginning to stray somewhat out onto a philosophical morass here, but I think it is still worthwhile to consider the communicative potential of other modes - especially modes in which people may be less aware of their own instrumentality.

Humans, like most animals, communicate a great deal with their bodies, not only with position and movement (proxemics), but also through active ornamentation and display through apparel and action. Body language in humans is often a relatively unconscious behavior, but we also use it instrumentally in some situations. When they are being threatening, charming, or seductive, people tend to actively deploy cues of position, gesture, and expression as part of a behavioral collection aimed at producing a certain effect. Some of these cues seem to be relatively "hard wired", while others are highly culture, locale, and context specific. Even very young infants show a smiling response when shown a smiling face. All humans tend to maintain a "personal space" between conversational interactants, and the distances often change as the relationship between the people changes. But the distances also very systematically depending on the ethnic background, class, and power relationship of the

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think there are any Viet Cong in the hamlet, burn it down.' The company commander told his troops, 'Burn

interactants. (Hall, 1966)

Proxemics and facial expression can communicate a great deal of information about the emotional status and intentions of an individual, but they are also used as signals from in-groups to out-groups. Couples, for example, often exhibit "With" behavior (Goffman, 1971) in which they make displays which indicate the connection between them - that they are with each other - both to each other and to a larger audience. Goffman presents the interesting perspective that most of public social behavior is in fact a sort of role playing or semi-intentional display of behavior in a near theatrical sense. This role-playing, and its interpretation by observers, applies to everyday life, not just in situations in which there is an active intent to misrepresent.

> Here note that the expressive idiom of the individual's society and group ensure that evidence of his assumptions about himself will be made available not only through his performing of his main substantive obligations, but also through expressive means, comprising the way he handles himself while in the presence of others or while having dealings with them ... the individual exudes assumptions about himself. These provide others with a running portent, a stream of expression which tells them what place he expects to have... (Goffman, 1971, p. 344)

The idea that "behavioral communication" may be nearly ubiquitous should emphasize that information transmission does not require explicit linguistic behavior and may be almost unceasing and unavoidable when individuals enter into perceptual contact with each other.

As I have already mentioned, even a lack of communicative behavior can send a strong signal. This is true from both the social and information theoretic perspectives. There are often situations in which individuals convey disapproval through a marked lack of comment, or individuals may attempt to avoid interaction as a way of communicating anger or disdain. Socially, there is a great difference between not speaking to someone, and not speaking to someone of whose presence you are aware. In the information theory sense, absence of communication is a distinguishable state (perhaps the "space-between-words" character in Shannon's examples) which can have its own expected probability. If the observed frequency does not match what is predicted, information is transmitted.

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down the hamlet.'"

Even without its negative connotations, non-communication or off-hand communication (brief, stereotyped greetings, etc.) can carry information because of the social context in which they are embedded. Inaction or a failure to disagree is often taken to be a sign of social ratification of an existing situation or framing interpretation of what is happening. This is true not just in the trivial example of the Western wedding ceremony, but also as a consistent finding in social psychology. If you say "Good morning" to me and walk away, I can take that not only as ratification of a presumed relationship in which it is appropriate for us to great each other (and no more), but also as partial evidence that you are not aware of any information of sudden and dramatic importance, (imminent asteroid collisions with earth, rabid dogs in the immediate vicinity) and that my behavior conforms to your expectations as well. It is possible to interpret this as a part of a "social ratification" or conformity effect in which an individual's behavior is endorsed or opposed by a social group: "When changes occur, it is usually only when the individual perceives that his group approves, or that support comes from a dissident sub group, or from an outside group toward which the individual sees himself moving or whose presumed standards he accepts" (Menzel & Katz, 1955 ). As Stanley Milgram (1969) demonstrated in his classic studies of obedience to authority, the power of such conformity effects is remarkable, and often under-estimated.

Unlike most animals, humans have gained considerable ability to alter their appearance on an almost daily basis. Although clothing in its current elaborate form may be a relatively recent invention on the evolutionary time scale,[12] it is a powerful communicative element and shapes a great deal of interaction. Clothing and personal appearance provide powerful (and manipulable) markers of wealth, social and instrumental roles, group alignment, ethnic background, class, and event ratification. There seems to be some consensus that fashion choices are partially determined by imitation (Schrank & Gilmore, 1973). If so, fashion

[12] There are many possible sociobiologically styled arguments for why it might be adaptive to use personal appearance for signaling. High status items, like Armani suits for Western men, could function as the "peacock's tail" in sexual selection. They make you look good within a particular cultural schema, but they, and the accompanying appearance and lifestyle, are expensive to obtain and maintain, thereby providing a potentially useful indicator of wealth, power, and status to would-be mates.

displays can be considered cultural behavioral messages. Certain "clothing messages" might become associated with certain groups or social subcultures (or be adopted by the groups because of their symbolic properties). Once established, the association between the clothing and the group's attributes may become a stereotyped property of a larger cultural repertoire which can be drawn upon or "borrowed" by others. However, an effective reference requires that the displayer and receiver both have enough experience with the stereotype to catch what is being cited.

It is interesting to think of the role of fashion in identity display. Conformity and individuality can take on information theoretical properties in this context. If, in a group of people, everyone conforms very closely to the norm, no information is available to an outsider about any individual except the identity of the group category they have adopted. The perspective from within the group, however, would be slightly different. Because the properties common to all members are ever-present, they are not surprising; they carry no information. To an insider, only the subtle divergence from the norm will be noticeable, and members will be distinguished using characteristics which would be imperceptible to an outsider. Only the "gross" attributes of a group will be accessible to an outsider, until they have enough experience and familiarity with the norm to be able to make more finely grained categorizations. This may partially account for why, in segregated societies, people may say that members of the minority race "all look the same." If this is in fact the case, there might be a fairly consistent ratio of trait contact (a threshold) at which members of the majority are able to distinguish among members of a minority, and this value might be derivable from information theoretic considerations. For groups, greater divergence from a norm facilitates the perception of individual identity, but too drastic a divergence among group members may weaken or eliminate outsider's perception of the identity of the group as a cohesive whole. As much as fashion is an active and strategic, rather than a passive and receptive choice, individuals must consciously or unconsciously strategize about what kind of displays will allow them to be classed with their desired group while still presenting an identity as an individual

to various audiences, both inside and outside the group

These kinds of "strategic" adoption phenomena might drive interesting population-level trait patterns. To use dynamical terminology, the perceived group norm may act simultaneously as a repeller and attractor. The fashion transmission literature often assumes a phenomenon of leadership: there are certain individuals with desirable characteristics which others will try to emulate. (Schrank & Gilmore, 1973) Although the traits displayed by the "leaders" might initially act as attractors, they could also become repellers as they are assimilated by a group norm. If all individuals must present a display which is norm-divergent in order to proclaim an identity, but at the same time must stay norm-associated for acceptance and attribution to their relevant social groups, then there might be strong tendencies for directional or divergent drift in group or population averages. Because the normal value for a trait moves with the group distribution, it acts as sort of a reverse "carrot-on-a-stick." In a sense this is the "runaway trait" phenomena described by Boyd and Richerson (1988). In the case of clothing, the magnitude of the drift may be somewhat bounded, as it is subject to a few functional and aesthetic or "moral" constraints. There are, in fact, observable national trends in fashion measurements (such as dress dimensions of formal wear, see Figure 9) which occur

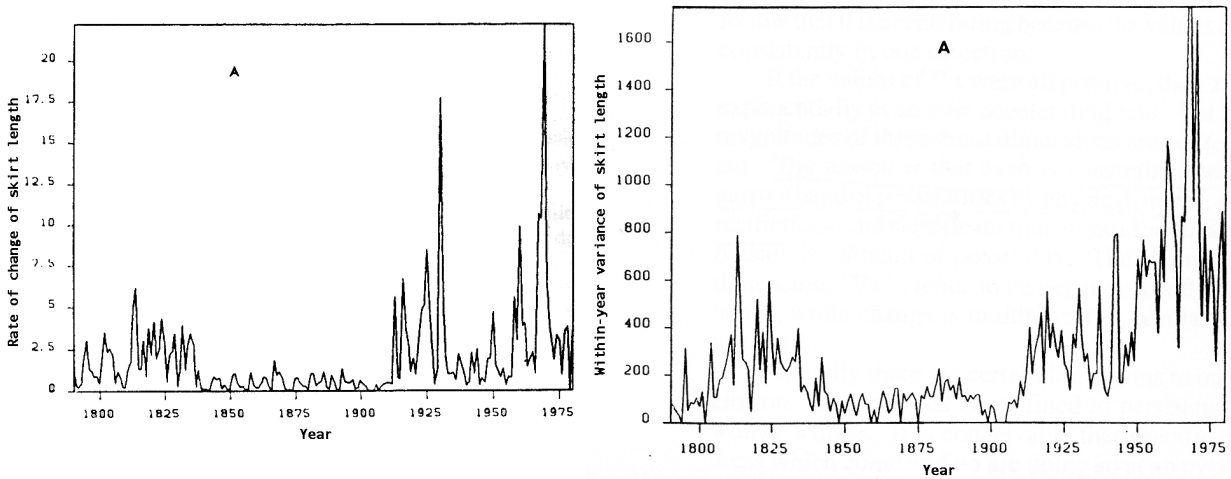



Fig. 9 Graphs show metrical measurements of skirt length of women's formal evening dresses taken from high fashion magazines and averaged to create yearly means. The first graph shows the rate of change (derivative) and the second shows the within-year variance of skirt length. (copied without permission from Lowe & Lowe 1990)

within very short time frames and frequently change direction. (Lowe & Lowe 1990)

It seems likely that there are many traits which, when compared to fashion, are more passively or unintentionally displayed and adopted - either because they occur early in development, are so normative to a culture that they cannot really be perceived until they are contrasted, or because the process occurs at such a "deep" level evolutionarily that individuals have no real control over display and adoption. Perhaps language would be an example of the first, and accent, dialect and cultural institutions are examples of the second. Although this is really just speculation, culturally determined sex roles and courtship behavior could be an example of the third. (There might be strong evolutionary pressure to conform to local courtship patterns.) For a trait to be "invisibly" transmitted in the second sense, it would have to occur with a high frequency in the population or group with which an individual is in contact. As I discussed earlier, what appears normal to one sub-group need not be normal in another, and, if groups are segregated, the group norm doesn't have to agree with the average of the en

It is important to consider what other structural or contextual features might permit the formation of groups or spatialized patchiness of attributes like dialect or accent. Historically, this could be due partially to the effects of physical distance and the effective isolation of human social groups. But so called "mass media" which allow the display and reception of information across vast distances have drastically redefined the structural framework withen which social information transmission occurs. Innovations like writing, printed material, and the book add complex temporal effects as well. When information can be symbolically encoded in a material form it can be preserved, lying "dormant" until it is stumbled across at some later date and decoded. The concept commonly employed to generalize the structural effects of mass media is one of diffusion, as opposed to impermeable isolation. The concept of diffusion in social systems is by no means new. The basic ideas, at least as applied to culture, have been present in anthropology in one form or another for at least 150 years. But do diffusion (or "epidemic" in the Blue Tits example) principles accurately describe cultural phenomena? How

about on the fine time- and space-scales of social groups?

Deutschmann and Danielson (1960) used phone interviews to track the "diffusion of knowledge of the major news story" in several cities. (Figure 10) Their work was based in part on Elihu Katz's (1957) hypothesis of the "two-step flow of communication" in which ideas often flow from radio and print to opinion leaders and from these to the less active sections of the population. It would be interesting to know what role conversations and contacts between individuals play, as well as how effective the news media are at conveying a particular message. Little is actually understood about what the dynamics of news items are once the newspapers reach the streets.

> ...Then follows a second stage in the history of the story, about which little is known. We call this the period of news diffusion because in it the facts of the story filter through community life - diffuse through it so to speak - color it, change its complexion, reach and effect in some way nearly every person in it ... It appears that for this class of events and general adult populations, one to two days is required for completion of the diffusion process even with full 'bulletin' and 'banner headline' treatment by the mass media. We found no rapid 'word-of-mouth' diffusion similar to that reported by Miller for his college sample. It should be noted that his respondents were homogenous, to a considerable degree spatially contiguous, and with a pattern of regular movement which naturally brought many persons in contact with many others. (Deutschmann & Danielson, 1960, p. 345)

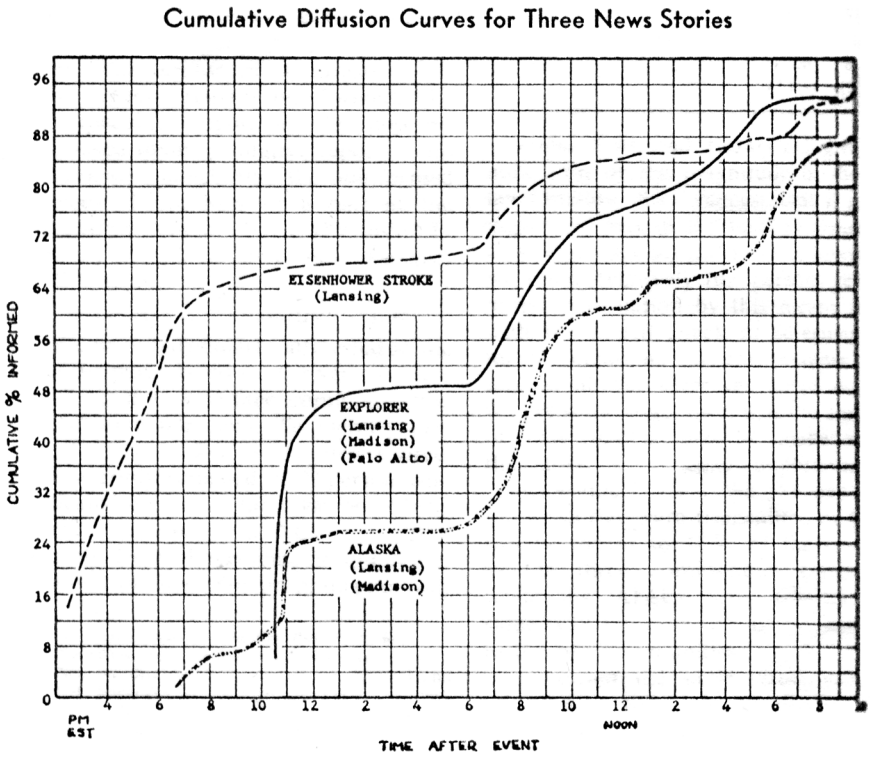



Fig. 10 Results of phone survey of knowledge of major news stories: President Eisenhower's stroke, the launch of the Explorer I satellite, and Alaskan statehood. (copied without permission from Deutschmann & Danielson, 1960 p. 348)

In their study, and in a related follow-up by Greenberg (1964), an emphasis is placed on the "importance" of a story as determining whether its transmission occurs more by direct contact with mass media or through personal communication. Both studies suggest that more important stories are more likely to be heard from personal sources. But to estimate the relative importance of social transmission it is necessary to consider how the news-worthiness of the item will couple with the normal patterns of social and media contact of a group: "Personal contacts play their largest role in diffusion when news is of greatest and least importance." (Greenberg 1964, p. 489) When news items are carried by the mass media, most people tend to learn of them from that source. But as usual, the specific content of the message may have strong effects as well: "Events which go unnoticed by the majority may be deliberately chosen [for transmission]... by the few because those events have some functional importance." And "gossip" news items which are only pertinent for members of a certain social group are unlikely to receive mass media treatment. There may also be strong self-monitored informational "boundaries" between social groups because members realize that their gossip will be of little interest to outsiders and so neglect to discuss it with them - making the groups effectively isolated with respect to certain dimensions.

The "two-step flow" literature based on Katz, and certainly the "diffusion of innovations" (Rogers, 1962; Valente, 1996) and the fashion-diffusion literature, often emphasize the idea that there are certain individuals who play the roles of brokers, opinion leaders, "early-adopters" or innovators. This may be more true of slower processes like innovation adoption in agriculture, but apply less to rapidly percolating phenomena like news or gossip. After a survey of relevant studies Katz points out that,

> ...It became clear that opinion leadership could not be viewed as a 'trait' which some people possess and others do not, although the voting study sometimes implied this view. Instead, it seems quite apparent that the opinion leader is influential at certain times and with respect to certain substantive areas by virtue of the fact that he is 'empowered' to be so by other members of his group. (Katz, 1957, p. 68)

This suggests that it might be important and worthwhile to consider the effects of social structure in more detail than the diffusion perspective permits.

## VI. Networks and Social Structure

Social relations tend to have an amorphous and ephemeral quality, making the term "social structure" at times seem like an oxymoron. Yet it is clear that there are also reoccurring patterns in individuals' social contacts, and both people and organizations often describe the patterns in terms of fixed relationships. The abstract ties of extended family lineages, social support networks, organized webs of informants, and hierarchical political organizations are frequently spoken of as structures or networks - sets of relations between individuals which may partially predict or explain their behavior. It is often useful to conceptualize these patterns of interaction, friendship, or aid as formal "webs" or "networks" in order to visualize them more completely, compare them, and analyze their properties. A formal network description usually involves delineation of the ties or connections which interrelate a group of individual actors according to some criteria. (Figure 11)

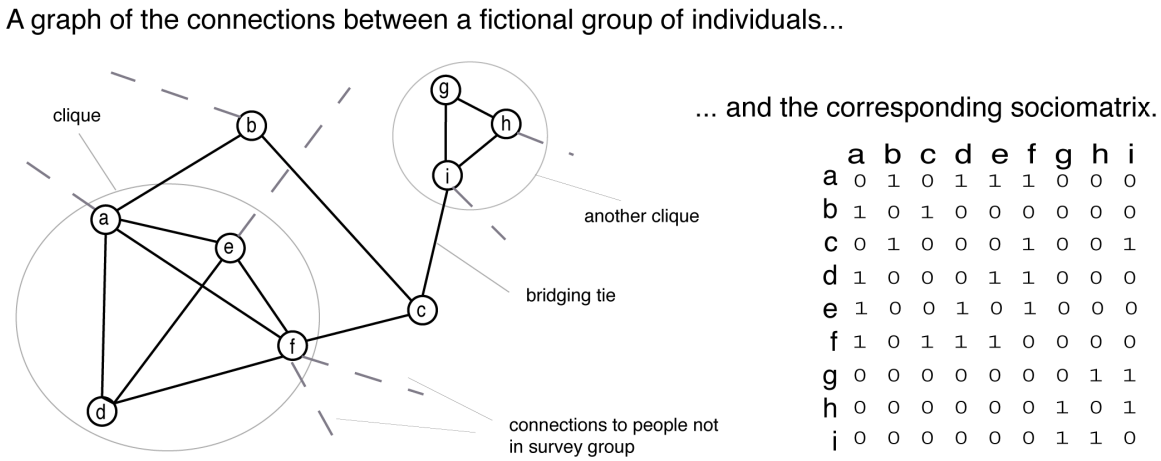



Fig. 11 An example of a graph of a simple social network and the matrix representation of its connections. Because this is a undirected graph, the matrix is diagonal symmetrical. Two cliques - full connected subgroups - are indicated with circles. A bridging tie is a connection that would break the network into two separate components if it was removed.

The actual meaning of the ties depends entirely on the data which they represent and the methods used to collect them. Descriptions of networks ("graphs") with real-valued or directional connections ("edges") can be used to represent strength relations, like friendship or frequency of interaction, or multiplicity (number of corporate directors in common), or number of academic paper collaborations between two individuals (Newman 2001a). Directionality is often used to include asymmetric relations and reciprocity: A likes B and B likes A, or Mary calls Dave, but not the other way round. Although it is not initially difficult to imagine representing social relations with a formal network description, in actual practice it gets a little dicey. There is a large number of ways in which individuals can be (or not be) related or connected to each other. And each mode of description could potentially generate a different network. In other words, the "picture" of the network of phone calls connecting a particular group of people could be quite different from the reported friendship network, which might even be different from the "true" network of friendships. It is crucial to remain clear that the concept of a social network is an abstract formalism, a tool for analyzing structure by representing relationships in a form which is amenable to computation and descriptive statistics. A social network is different from the network of telephone lines or the national power grid in that there are no literal connections among the actors. Rather the ties in a social network represent shared attributes, interaction probabilities, observed social support, etc. A distinction should also be made between an abstract "collective social network" of actually existing relations, and an individual's personal concept of it, a "cognitive network." (Marsden, 1990)

It is often quite difficult to obtain data which can be used to create network descriptions. In some situations there are hard data available (paper citations, telephone call logs), but in many cases the data can only be obtained by asking people questions. This means that the results are subject to all the errors, biases, and interesting quirks of any social science research. For example, people may be unavailable, unwilling to give complete information, unable to accurately recall the parameter of interest, confused by the question, or incapable of

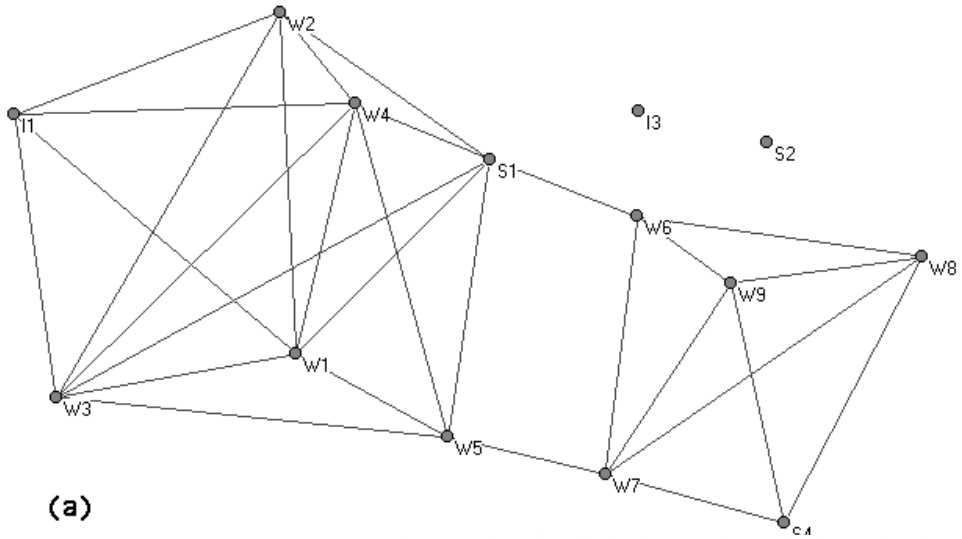
giving an objective response. The cognitive representation of a network which is obtained by asking network related questions may not entirely match the actual network under study (Marsden, 1990). Another approach would be to observe people and record the instances of whatever action or interaction is of interest as they occur. This would be feasible if the intention is to describe a small collection of typical "ego-centric" networks, but much more difficult if a snapshot of the full connectivity of a large group is the goal. The distinction between ego-centric and group connectivity (a large collection of overlapping ego networks) descriptions also brings up the bounding problem. If the idea is to get a complete description of possible connections among people, how do you decide where to draw the line around a group of interest? At what number of removes do connections cease to be relevant for the question? Some questions suggest networks that seem to have clearly delineated boundaries - information flow between the working groups of a specific company, for example (Rentsch 1990). But for others, limiting the data to individuals on the company's payroll might leave out some crucial connections - perhaps one of the chief engineers is sleeping with the CEO's wife and gets early warning of firings.

Caveats and cautionary conditionals aside, there has been some fascinating work done from a social network perspective with immediate relevance to questions about culture and information transmission. Some of it directly addresses the questions above. Most of the analytical work has been done within the framework of Graph Theory. Many of the properties of ordered lattices, such as percolation of epidemics and path length scaling, have been formally described and analyzed. (Goldenberg, et. al., 2000, Gupta et. al., 2000, Huang, 200, Newman, 1999, Watts, 2000) On the other end of the spectrum, graphs that are completely random (show no recognizable structure or pattern) usually are even easier to deal with analytically. (Callaway et. al., 2000, Friedkin, 1981, Newman, 2000, Rappaport 1953, Rappaport et. al., 1989, Watts 1999) The area in-between, where networks show some structure but also some degree of random connectivity, is much harder to describe formally. Most of the work on "partially-ordered" graphs is done with computer simulation. There has been a recent

re-emergence of discussion and work on these "small-world" and other social network problems. (Ahmed & Abdusalam, 2000, Moore & Newman, 2000, Newman, 2000b, Newman & Watts, 1999a, Newman & Watts, 1999b, Stevenson, 1997, Watts, 1999,) Fresh interest may be due partially to recent advances in theoretical tools and computing power, but it is also because of the recognition of related problems in several disciplines - neurons, metabolic pathways, and ecological food webs also form networks.

Ongoing attempts are being made to determine some parameters and graph-theoretic properties of network data collected from human social networks. (Foster et. al., 1961, Klovdahl, 1989, Watts, 1999, ) Although I have not encountered much in the way of conclusive evidence for overarching statements, there does seem to be some consensus about some of their qualitative properties. A great deal of the original research was aimed at establishing the existence of, and hashing out definitions for, sub-groups or cliques within social networks. The terms "clique" or "set" are commonly used by individuals in ordinary conversation in the process of describing or explaining social relations. It appears that there is some empirical basis for the common language practice of dividing groups up into subgroups, but the distinctions are rarely clear cut. Just as in common use, there are always people who don't quite fit in one category, and the group definitions almost seem to break apart under close inspection. Part of the reason for this may be a confusion of categorical groups defined on the basis of personal attributes (clothing style, academic participation, etc.) and groups defined by actual interaction. But it is also fairly clear that interaction or friendship networks actually do containing various degrees of hierarchically clustered subgroups.

In some of the early studies, the networks under consideration were fairly small (~ 20 people) and were derived from co-participation matrices in events or interactions. In his paper on analyzing and visualizing clique structure, Lin Freeman (1996) mentions a study in which several anthropologists recorded incidences of game-playing and conversation between coworkers in the Bank Wiring room in a factory of the Western Electric Company. They[13] also recorded their impressions of the structure and functioning of the group and the roles of its various members.



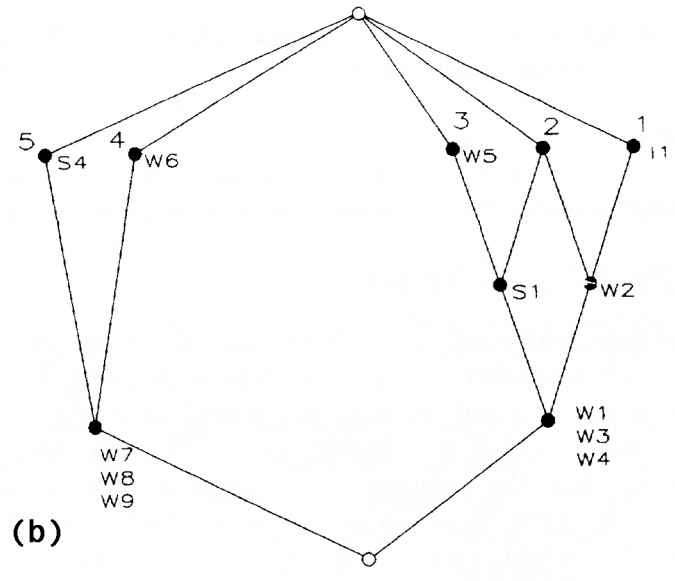




Fig. 12 Network graph (a) and Galois lattice of cliques (b) for the Roethlisberger and Dixon (1939) observational data on game playing among the workers in the Bank Wiring Room in a Western Electric Company factory. The Galois lattice diagram (b) shows the pattern of overlap in cliques found in the network. The top-most point represents the pair of subsets containing the set of all 12 individuals and no cliques. The bottom-most point represents the pair containing the set of all five cliques and no individuals. (lattice image copied without permission from Freeman 1996)

[13] Roethlisberger, F.J. and W.J. Dickson (1939) *Management and the worker* Cambridge, MA: Harvard University Press

There are many ways of formally defining subgroups in networks. In graph theory, the term "clique" is usually reserved to mean a completely inter-connected sub-group; all of the members of the subgroup are connected to all the other members. In most cases, these formally defined cliques do not correspond well to the common usage sense of the term. It is generally the case that many of the formal cliques present in a graph overlap to a large degree, sharing all but one or two members. This pattern of overlap can be formally analyzed and group structure can be inferred. There are many procedures for doing this, but the general idea is to provide a picture which shows which individuals are present in which groups as the strictness of the definition of the groups is relaxed one step at a time. (Fig. 12) Although the computational tools were not available to the anthropologists at the time of the bank wiring study, Freeman's subsequent analysis of the hierarchical clique structure arrives at divisions of subgroups which are very close to the impressionistic ones given by the observers at the time of the study.

Another important property of social networks, which also appears to some degree in cluster diagrams, is that of the "bridging tie". The concept also comes from the intuitive sense that in social networks there are often a few individuals who provide a connection or act as a bridge between structurally separate groups. The idea was well developed, and some of the striking implications were pointed out, in Mark Granovetter's classic "Strength of Weak Ties" (Granovetter, 1973). To paraphrase his argument: There is a good deal of evidence for strong auto-correlation effects in friendship and acquaintance networks. That is, because of the amount of overlap in fully connected cliques, it is very likely that, not only will most of my friends know each other, most of their friends will be my friends as well. This may mean that we are likely to be present at the same events, share a similar sub-culture, and know similar things. In this kind of situation, individuals who are members of more than one group, or ties which are "weak" but bridge large social distances, may have strong effects because they have access to views or information new to the group: "...weak links are better at spreading information widely, but strong links are better at locally creating the common knowledge." (Chwe, 1999, p. 128)

The inclusion of this small dose of randomness in the form of long-range connections between tightly clustered sub-graphs can drastically alter the topological properties of a network. One measure which demonstrates this clearly is the scaling of the average graph-theoretic distance between nodes for different sized networks. Graph theory measures the distance between two nodes as the number of intermediate steps necessary to travel from one to the other along the network connections ("edges"). To obtain the average distance for a network with N nodes, a large number of node pairs are chosen at random, the distance between them is calculated, and the results are averaged. This crude measure doesn't say that much about a specific instance of a network, but if the average distance is calculated for a series of graphs with increasing N and similar topologies, comparisons can be made between different topological classes. For most "regular" topologies (grids, chains, rings, stars, etc.) the average length increases as a roughly linear function of N. But for fully random graphs, the average path length increases only as log(N). (Newman & Watts, 1999, Watts, 1999) And the transition is fairly rapid. Just a small percentage of random connections are enough to noticeably change the scaling curve. (Fig. 13) The reason for this is really pretty intuitive. The greater proportion of random connections or bridging ties there are in a network, the more likely it is that one of my network "neighbors" will not only be a member of my local "neighborhood," but will also be a member of a neighborhood which would otherwise be at a great distance from me.

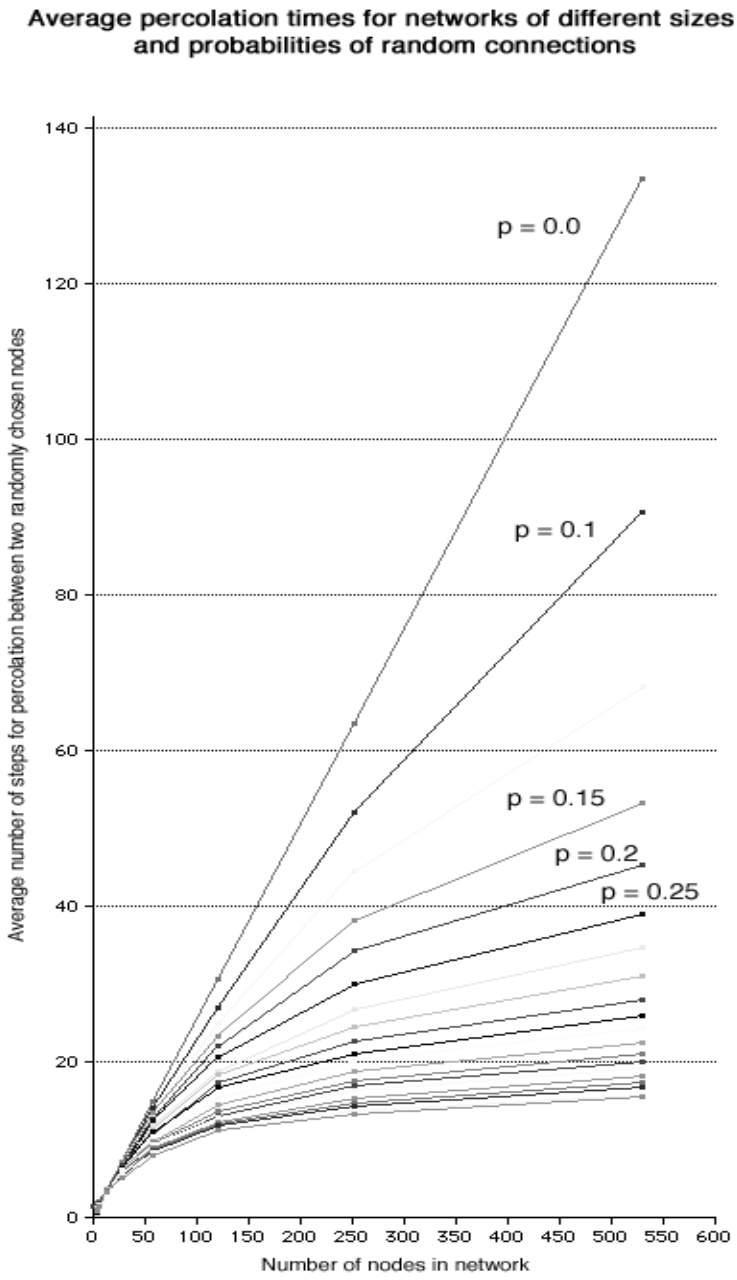



Fig 13 Graph shows the results of a simulation of the effects of different properties of random connections on the average time required for percolation between two randomly chosen nodes.

This is part of the formal explanation of the "small world" or "six degrees of separation" phenomenon. Although it was probably first brought to the attention of the academic community in a series of striking experiments by Stanley Milgram (Travers & Milgram, 1969), the "small world" idea is something people have been noticing for a some time. Why is it that when meeting someone for the first time it is often possible to discover a mutual friend or acquaintance at some distant (or not so distant) remove? At first this seems rather

counter-intuitive, but consider the results of a theoretical percolation or epidemic in a social network. "What is the probability that any two people selected arbitrarily from a large population such as that of United States, will know each other?" Or, a question more relevant to a discussion of transmission, what is the average length of an acquaintance chain connecting two arbitrarily chosen individuals?

Crude estimations of the number of friends and acquaintances of an average individual are on the order of thousands (Watts, 1999 ), where the population of the world is on the order of billions. The random connectivity helps to break the clumpy auto-correlatedness of social groups. But even if social groups are "cliquey" to such a degree that each individual had only 10 friends which were not shared with their correlated group of friends, if each friend sends a message to each of their friends, the message could reach a million people after only six transmission stages. If a message is intentionally rather than passively transmitted, individuals can utilize their knowledge of the networks to shorten chains even further: If I wanted to send a message to an Australian aborigine but didn't know anyone in Australia, I might first send the message to a friend who had a friend in an embassy, who might pass it to an Australian diplomat...

The theoretical connectivity may not be very consistent with practical considerations. If everyone used social networks rather than the postal service to send messages to aborigines, we'd spend all of our time sending other people's messages. Any models of rumor or cultural trait transmission must include such attenuating factors as bandwidth restriction (an individual only has a certain amount of time available for communication in a day), various kinds of costs,

and of course the myriad possible errors and biases inherent in serial transmission tasks. The small-world properties of social networks make for good anecdotes and provide the

potential for clever exploitation in certain circumstances.[14] The high effective connectivity may explain why some things spread quickly and thoroughly, but it is also important to consider in more detail the properties of networks which work to prevent total homogenization and diffusion of cultural traits and messages. I'll discuss this further in the next section

The representations of social networks which most interest me are those in which the ties are real-valued and indicate the relative probability of contact or interaction between individuals. I believe that it is essential to include background levels of noise in the contact model so as to allow for the occurrence of "random" interactions between individuals- neighbors bumping into each other, etc. A network described in this fashion would be "fuzzy" rather than deterministic (Xiaoyan, 1988). Because the relations between people change over time, the conception of an interaction network should be dynamical as well. That is, although networks are commonly visualized as a static "slice", it is important to be explicit about the time frame the data describe or from which they are aggregated. The question of what parameters control how a social network grows and changes is a fairly open one. One might expect that circumstance, shared culture, personal attractiveness variables, spatial proximity, demographics, work relations, and existing networks would all have some impact. It may be conceptually useful to break apart the various causes, separating out the various "component" networks of forces which act in combination to produce the observed network of interactions.

[14] It would be interesting to consider whether the proliferation of 'Junk' email - petitions, bad jokes, rumors - is related to the relative simplicity and low cost of serial transmission tasks in the medium.

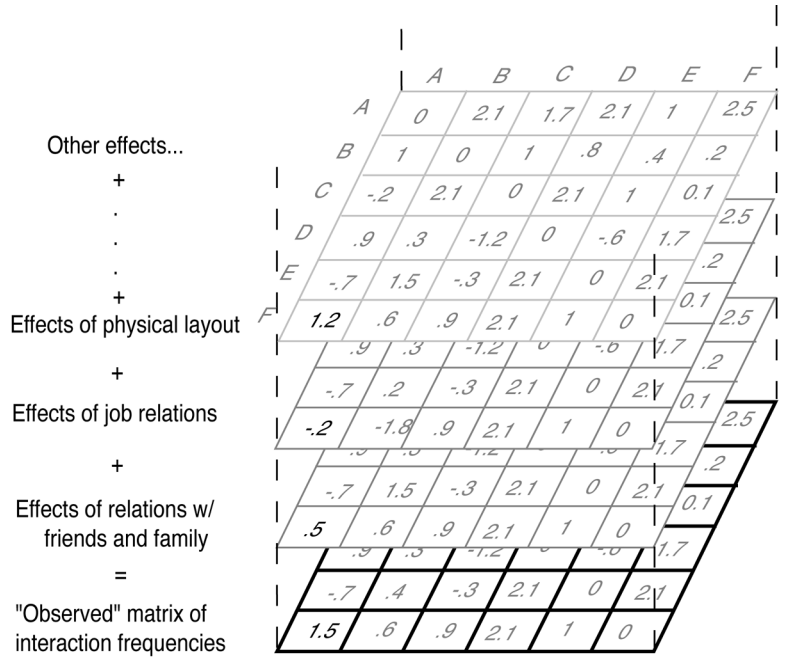



Fig. 14 Image illustrates metaphor of the "observed" interaction network as a summation of the effects of various arbitrary classes of structural variables. The grids are intended to represent the matrices of the "slice" networks. The value in the lower left corner, for example, is the sum of the positive and negative effects of the various relational networks above it.

One of these "slice" networks might describe the portion of interaction probabilities which are due to spatial proximity. In it individuals who live on the same block will have much stronger ties then those who live in distant cities: "environmental embeddedness." Another slice might describe the impact of existing relationships on the formation or dissolution of ties (triad balance, etc.). This is, I believe, what is meant by the notion of "structural embeddedness" (Feld, 1997) It would be possible to describe job or institutional structure as one of these slices. An individual who works in a specific capacity may have a formal network of functional relationships, interactions which must occur for them to carry out their assigned tasks but which are essentially independent of who fills the role. These slices and their layered aggregates are really only a means of trying to concretize conceptually the effects of social forces on the relations between individuals. In actual practice they are all interrelated:

> Communication, exchange and normative contents of the linkages in social networks are all intermingled in real social institutions for all social interaction involves communication, explicit or implicit, some exchange, and evaluation of behavior in terms of social norms. Whichever we choose to emphasize will depend on the sort of problems we are interested in. (Boissevain & Mitchell, 1973)

Not only do these component networks simultaneously "control" individuals' behavior, but they

may quickly begin to influence and reflect each other. Work- and neighbor-networks may quickly become friendship networks. Antagonistic relations in job situations may cause the actual patterns of communication to diverge radically from the formal organization-chart representation of an institution.

I suggested in the section on cultural transmission that this aggregate contact network, the representation of the actual interactions in which a person has participated, could be used as a crude predictor of cultural transmission. That is, it may be possible to ignore most of the details and content of interaction and simply assume that each time individuals interact some information and cultural traits will be exchanged. Viewed this way, the transmission of a specific item or connotational loading would be probabilistic, but its distribution in a population would, after a period of time, reflect the distribution of interaction probabilities between the members of the population. If, as I'll discuss in the section on conformity by association, one of the strong measures influencing contact probabilities is the degree of shared culture, then the rate of "transmissibility" of an informational item compared to the rate of change of the network becomes an important consideration.

Swiftly moving items can take advantage of the small world effects and diffuse widely and rapidly. Slower moving cultural traits, like religious or political affiliation, have the potential to alter the shape of interaction networks as they are transmitted. Groups which are initially formed by chance may become stronger as members' interactions are increasingly biased toward each other - and this might in turn cause increased frequency- dependent effects as the relative number of similar traits increases. The differences in rates of transmission for different items can even be given a probabilistic gloss: A slow moving trait may be one which is composed of a large number of interdependent concepts which must be co-present and integrated before it is usable or detectable. If we still assume that the receiver is trying to assemble all of her incoming information into a coherent whole, but the source is randomly transmitting the elements of the trait (or vice versa), it make take a considerable number of contacts before the receiver can assemble the same message as the source or demonstrator.

It is also possible to take a more fine-grained approach and imagine the interaction network from the perspective of the information being transmitted, rather than individuals' contact frequencies. Some kinds of information may only be transmitted in certain contexts or with certain pre-conditions. Information which is context dependent may require that interactants share the same context for transmission to occur. Some kinds of confidential work-related information might only be discussed with certain work-mates, for example, so the network as "seen" by a piece of confidential information might be a small subset of that which is seen by an item of gossip about the president. Or to put it another way, each individual may have probabilities of discussing certain topics. For an item or valence to be transmitted between two arbitrarily chosen individuals, they must come into contact (interaction probability) and discuss the topic or context to which the item or schema-component is linked[15]. If the individuals do not share any of the contexts with which the information is associated, transmission is very unlikely. This might explain why information which is relevant to a large audience is transmitted widely and rapidly. If something can be discussed in many contexts, the likelihood of it getting talked about in a given interaction is much greater- the number of different context-dependent sub-networks which it can be transmitted along is much larger. A good way to visualize this idea of context-dependent networks is to think of the image of a large multidimensional stack of traditional network matrices. As in the example in Figure 14, each slice can show the transmission probabilities for an item which is associated with that context or setting. The actual network of probabilities for a specific item would be the sum of the networks for each of the contexts associated with the item.

[15] For an interesting paper on representing the transitions between different 'modes' of discourse in dyadic conversations as Markov process, see Thomas, Roger and Bull (1983)

## VII. Dynamics of Conformity and Association

In the previous sections I've made some speculative predictions, both at the level of the individual or dyad and also at the level of groups, about the dynamics of information which is socially transmitted. One thing which has become apparent to me as I become more familiar with decentralized systems and emergent behavior is that it is extremely difficult to guess what the system's global performance will be, even when the rules of the components are fully understood. It might seem that many of the statements I've made about the properties of social networks and information transmission imply dynamics which would lead simply to a general homogenous mixtures of transmitted culture. Yet there are many real-life experiences of social structure and transmission where this is not the case. How could simple transmission rules create complex patterns? What are the potential impacts of cultural transmission for the creation and modification of social groups? What classes of processes might drive group formation and dissolution, and how does the presence of groups in social structure affect transmission and population-level properties?

A recurring result of research into the behavior of systems is that even simplistic problems which have intuitive results become much more complex when the problem is spatialized. What I mean is that when notions of space, time, and distance are explicitly coded into the rules governing the operation of a system, it may show behavior which is radically different than when assumptions of homogenous random mixing or instantaneous effects are made.

An example of this are the Lotka-Volterra based models of predator-prey relationships in which the size of one reproducing population (the "foxes") is dependent upon the size of another (the "rabbits"). Because the foxes only eat rabbits, if the number of foxes were to increase beyond a certain point, there wouldn't be enough rabbits to feed all of them and the "extra" foxes would die. In the most simplistic case, the numbers of foxes and rabbits in the system would change until they achieve a balance, and this equilibrium point would be

dependent on their relative rates of reproduction. However, if the model is made more realistic by allowing factors like a time lag between the birth of extra foxes and their eventual death due to starvation, the relationship between the two populations becomes much more complex. The extra foxes may kill off too many rabbits, eventually causing the fox population to dive below its equilibrium level because not enough rabbits can be found. The rabbit population can then increase because there aren't as many foxes eating them. Once the rabbit population increases, the fox population may as well. Depending on the parameters, the populations in the system will crash to extinction, get locked into alternating cycles, or in some cases, jump around chaotically. (Bar-Yam, 1992, p. 586) This example exhibits complex behavior in time, there are corresponding effects in the spatial realm.

The near indistinguishability of cause and effect seems to be one of the essential complications for any analysis of social systems. Social structure is generated by the interaction of individuals but at the same time it guides their interactions. In essence, each step in time takes as its input the output of the previous step. This non-linearity, or dependence on previous states, is usually one of the prerequisites for the interesting classes of behavior exhibited by complex systems. Non-linear systems often have the potential to drift into either chaotic or well ordered states, depending on the initial conditions and driving parameters. This might mean that any chance occurrences of structure in the initial conditions of a system could be drastically emphasized through iterative processes: effects which are seemingly insignificant on the level of individuals could be drastically amplified at the population level. The opposite could also be true - the structure of the systems might be such that the starting conditions do not matter; the system will always progress to an "attractor" of a certain set of states. My point is that models of social process, and the tools for their analysis, need to explicitly consider these sorts of complex, time-based interrelationships. Contemporary theory is getting better about this, but is easy to slip back into a pattern of thinking of external causes directly producing observable effects.

Ole-Jorgen Skog (1986) presents a fascinating analysis of population level trends in

alcohol consumption data in Norway. (Figure 15) The data show interesting periodicities, but frequency analysis shows that the time series is qualitatively similar to one which could be produced by a random walk.

> Thus we may conclude...that very long waves of alcohol consumption exist, but [the analysis] does not necessarily support the idea that these waves are the result of systematic and long-term processes with a persistent direction. The results obtained in the time domain could even be taken to suggest that something resembling a random mechanism is at work. (Skog, 1986, p. 12)

He then presents arguments suggesting that if an individual's alcohol consumption is related to the consumption of her peers, the structure of the social network might be such that there is some degree of "coupling" of individuals' choices at the group level: "I have argued that long-range indirect ties may create sufficient integration in very large populations to produce a breakdown in the law of large numbers." (Skog, 1986, p. 29) In other words, if the social effects of drinking culture are strong enough, individuals may not be independently making their choices about how much to drink. Social groups may tend towards internal homogeneity, "choosing" as a whole at each time step, rather than averaging out individual's choices.

Skog's analytical results are important because they show that it is at least hypothetically possible for the coupling of individual choice and social structure to drive a cultural parameter to values which are not what would be expected if each individual acted according to some internal preference model. The problem is analogous to one in the US system of electoral voting: due to the discrete nature of a State's choice in the electoral college, a candidate can lose in

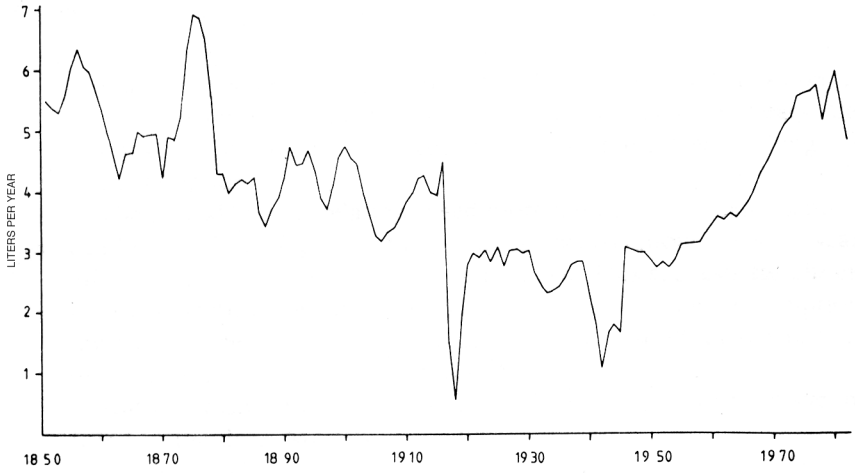



Fig. 15 Graph shows alcohol consumption per capita 15 years and older in Norway 1851-1982. Prohibition in Norway lasted from 1916 to 1927. (copied without permission from Skog 1986 p.6)

the popular vote and still win the election. Skog is arguing that the implicit rules of culture may create the same kinds of paradoxes as the formal rules of an electoral system do. Also, the actual dynamics of cultural phenomena may be more dependent on previous states of the system and interaction strength than on some of the presumed economic or legislative driving parameters. Although observed per capita alcohol consumption is certainly not totally historically independent, prohibition does put a big notch in the curve.

But how strong are the "internal homogenization" effects? Joan Rentsch (1990) published an interesting study of interaction and changes in organizational meanings in an accounting firm. She used interviews to collect lists of events and polar terms used to refer to them. The employees then took a survey which asked them to rate the meaning of various organizational events according to the polar terms. She also collected self report interaction data so that subgroups could be identified by using social network analysis. The hypothesis was that the service staff of the accounting firm in the study interact with each other more than with the heads of the firm, so the staff may interpret events in ways similar to each other, but quite different from the conception of events held by other "higher up" groups: "The results provide evidence that people who interacted with each other had similar interpretations of organizational events and that members of different interaction groups attached qualitatively different meanings to similar organizational events." (Rentsch, 1990, p. 268) As in every study of this kind, the actual causality must be inferred. Perhaps the formation of groups with similar view points is a result of people's preference for people similar to themselves, rather than solely a result of the interaction. Probably both processes are in effect.

Interactions which lead to increasing similarity among the participants would not necessarily lead to loss of diversity at the system level. Axelrod (1997) has written a compelling paper on a simulation in which agents were located on a spatial lattice and exchanged portions of their "culture string" with their neighbors. The simulation was set up so that the probability of exchange was greater for agents whose strings were already similar.

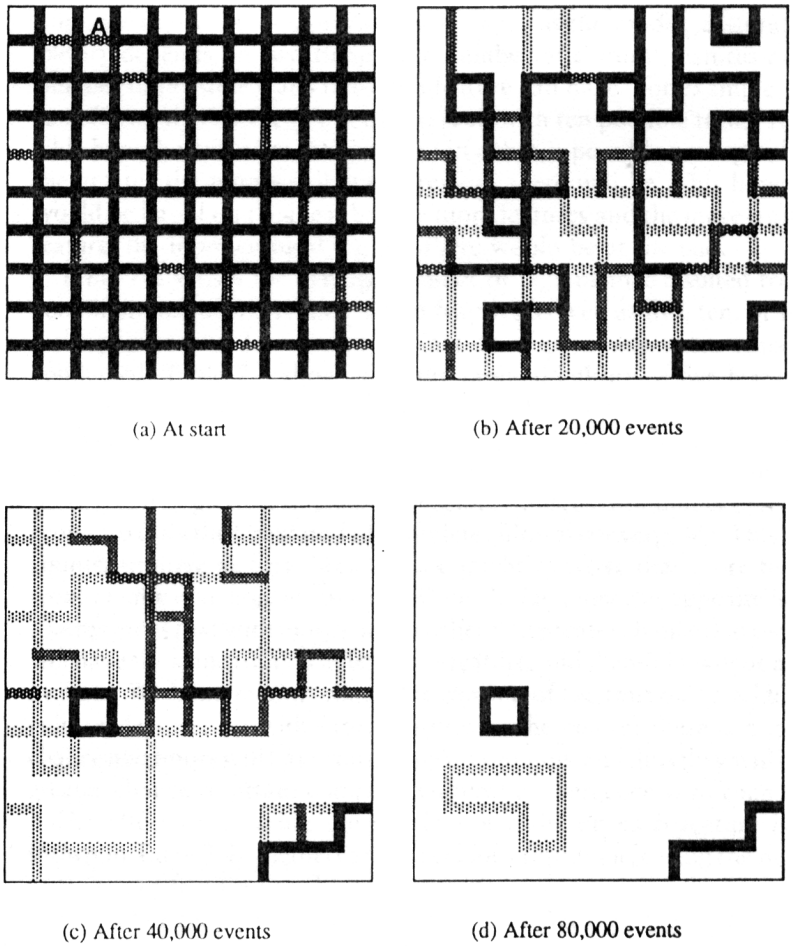



Fig. 16 Each map shows "cultural similarity" between cells in Axelrod's simulation at different points in time. Similarity of the culture strings in adjacent sites is coded as: Black < 20%, Dark Gray = 40%, Gray = 60%, Light Gray = 80%, White = 100%. This run was conducted using five cultural features and ten traits per feature. Each site has for neighbors. (copied without permission from Axelrod, 1997)

Runs of the simulation generally resulted in the emergence of a structured pattern of associations between agents (Figure 16). The distribution of the attributes held by the agents on the spatial grid showed a large degree of "patchiness". It seems reasonable to assume that the same kind of phenomena might occur in real human groups. However, the model has not been investigated in depth to determine which structural properties are necessary. It is likely that it would require some sort of discrete trait (or discrete informational unit), as well as preferential association based on detectable possession of traits.

Kathleen Carley (1991) presents a related model in which agents are not restricted to interaction with their immediate neighbors, but are members of a fully connected group social network. She tracked the existence of groups (measured as collections of agents with mutual

interaction probabilities greater than their probabilities of interactions with the rest of the population) as the agents exchanged information with interaction probabilities weighted on the basis of the number of "facts" in common. In contrast with Axelrod's model, all of Carley's simulations eventually converged on mutual interaction and a homogenous distribution of facts. (Fig. 17) However, the time to convergence and the dynamics were strongly effected by the relative sizes of majority and minority groups, initial network conditions, and proportions of shared knowledge.

Clearly the specifics of the design of the models are very important. Carley was mostly interested in the dynamics of a very small population - her largest group was 12 individuals. It would have been fascinating if Carley had run a simulation on a social network which was analogous to Axelrod's lattice. In one sense, the difference in results between the Axelrod and Carley models is encouraging. The formation of groups and subcultures in the real world is a complex and unpredictable process. And some cultural elements are more homogenous that others. The fact that changes in the subtle specifics of model implementation and

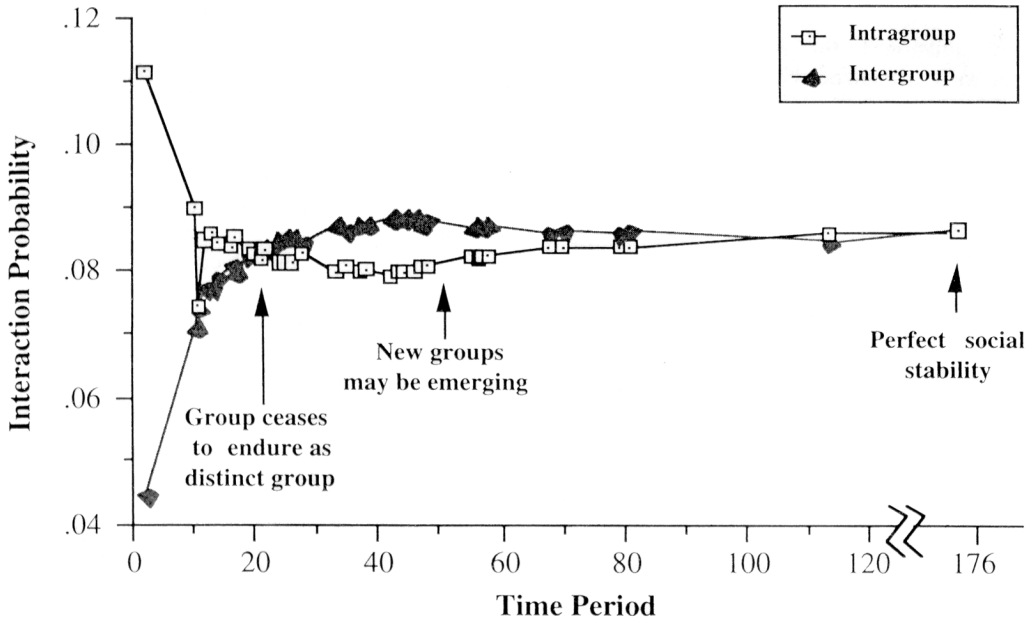



Fig. 17 Sample run from Carley's simulation of group stability. Plot shows relationship between Intergroup and Intragroup interaction probabilities over time for one group in a two-group society. (copied without permission form Carley, 1991, p.343)

parameters give divergent end results would seem to indicate a class of systems that is highly dependent on initial conditions and parameter values.

If interaction is, in fact, partially linked to the degree of shared culture among individuals, it is intriguing to consider the roles, and even potential adaptive value, of rituals and traditions which increase the degree of shared knowledge among participants. "Social" events may accomplish their intended purpose both by allowing people to meet, and by providing a base of shared events as a context for future discussion and interaction. Cultures which manage to maintain traditional events or rituals may be strong because the shared actions and experience of a ritual provide common cultural referents for group identity, a common "dictionary" for description, and a focus for coordinated activity and contact.

Chwe has an interesting discussion of parades and political displays as techniques for creating common knowledge among a constituency: "During the French Revolution, political symbols and rituals were not metaphors of power; they were the means and ends of power itself"... "Since submitting to an authority is a coordination problem, an authority creates ceremonies and rituals that form common knowledge" (Chwe, 1998, p. 51). He points out that one of the main functions of a parade is for the crowed to see itself. Groups often indicate membership, rejection, and alignment though semi-coordinated actions, so mass participation is an endorsement or rejection which is visible to all the participants: everyone knows what they saw, and that everyone else saw it too, and that everyone saw them see it.

A perspective focusing on the role of shared social information in the formation of group structure encourages closer examination of common social features that involve information spread. Gossip can take on an new adaptive role in this framework. Not only would it have strictly informative properties and normative effects through enforcement of cultural mores, but it also would be a means of allowing individuals who are rightly group members but who were not all present at a particular event to share in the common knowledge base. "In order to be recognized as a familiar group member it may be advantageous to acquire certain arbitrary or

ritualized behavior patterns" (Nicol, 1995, p. 86). Gossip keeps people from being "left out" and reinforces the structure and distinction between groups along the lines of the actors' conceptions of the groups. The function of mass culture and media might then have strong effects on the identity and functioning of subgroups. Broadcast media like TV and newspapers can be thought of as conveying normative social information or gossip to a broad population, and might conceivably drive individuals to identify with the broader group at the expense of their local subculture. The media are gossip on a large scale, acting as a unifying and homogenizing force. "The Simpsons" becomes a common cultural referent, a topic of discussion, an explanatory touchstone, and replaces the legends and myths which pertain only to specific subcultures.

## VIII. Models and Definitions

> All networks can be represented solely in terms of the connections between their elements, assuming that whatever combination of factors making people more or less likely to associate with each other is accounted for by the distribution of those associations that actually form. ... The likelihood of a new connection being created is determined, to some variable extent, by the already existing patterns of connections. (Watts, 1999)

Because the actual functions governing the when, where, and amount of information transmission are so complex and context dependent, there are a great number of dimensions for conceptualization, experimentation, and analysis. I've already mentioned some previous work involving the effects of status and trust on transmission. There are numerous other possibilities to examine: power, transactional exchanges, sex differences, etc. As the problem is so multidimensional, it is difficult to ascertain which perspective would provide the most informative perspective from which to view the data. And of course which variables are relevant also depends on what scale the phenomena are examined and explanation is desired.

To me it seems most effective to place less emphasis on the standard sociological variables like class, sex, wealth, age, race, profession, power, high-culture/pop-culture, eastern/western, trust, or physical attractiveness, and focus simply on contact and interaction frequency. My intuition is that, assuming culture to be generally a phenomena of socially mediated information exchange, any understanding of the dynamics of social interaction will shed some light on the dynamics of information and culture as well. As in every other case where a highly-dimensional problem is looked at through a low dimensional lens, focusing on contact means that many interesting variables will be lumped and collapsed together. But the advantage of focusing on interaction is that many of the other variables can be re-expressed as actor- or attribute-specific biases away from the central tendencies or patterns of interaction. And all of the unexplained or as yet undiscovered parameters can be included by allowing for noise in a model.

Locating and tracking the instances where interaction contacts occur would obviously be difficult, but not quite as unimaginable as tracking information itself. One question that immediately crops up is how to decide what degree of interaction constitutes a contact. What kinds of unintentional communication should be considered? What level of involvement is required of participants? For the time being, it makes sense to use a very broad definition. I'm using the term "contact" to mean that a person, a representation of the person, or some symbolically coded representation of the person's communication, has become perceptually *available* to another person. In this sense, the probabilities of contact and interaction are relatively synonymous: both could be described as the likelihood that specific individuals will "bump into each other" in a given time period.

Whenever there is contact, there is a probability that information exchange of some sort and degree will occur between the participants. As the participants continue to interact, information items which they have picked up in an earlier contact my be spread to their future interactants. I have argued that this may lead to increased similarity on some hypothetical metric for culture and meaning. Each specific information "item" or message can have its own

transmission probability. This probability is generally not equal to one, because it is always possible that the information will be disregarded, or that other information necessary for its comprehension or retention has not yet been received, so transmission effectively fails to occur. Transmission probabilities will, of course, be related to contact probabilities, but I'm defining them as based on a unit of time rather than an instance of contact.

For each level of analysis, the collected set of probabilities relating a group of individuals can be described as a network, and it is possible to relate the networks. From the perspective of the agent or actor, a network would describe the frequency of interactions with others and the structure of interaction groups. From the perspective of the "culture of the group", the network would describe the probability of exchanges which lead to increased or decreased similarity. From the perspective of a "unit of information", the network would describe the distribution of chances for transmission. I think that it is worthwhile to consider some kind of crude explicit formal model which can be used as a null case or conceptual reference point on which to elaborate later. The simplest baseline model I've come up with is one centered around the idea of a fixed pattern of interaction. That is, I'm initially viewing individuals as automatons with no will or intelligence, each of whom probabilistically follows her own "preset" pattern of contact relationships. The resulting network acts as a substrate for transmission, and information flowing through it approaches probability distributions related to the lengths of various possible interaction "chains" between actors.

The focus of analysis can be narrowed down to consider the transmission probabilities for one item of information in a population of individuals. If the probability of direct transmission of the item between individuals i and j in a given time period is indicated as $\mathbf{P_t(i{\sim}j)}$ and transmission between j and k as $\mathbf{P_t(j{\sim}k)}$, then:

$$\mathbf{P_t(i{\sim}k) = P_t(i{\sim}j)^*P_t(j{\sim}k)}$$

In other words, the probability of transmission of an item to an individual two steps away is equal to the product of the probabilities of each individual step. Of course there may $\mathbf{P_t(i{\sim}l)}$, $\mathbf{P_t(l{\sim}m)}$, $\mathbf{P_t(m{\sim}k)}$ such that:

$$P_t(i \sim k) = P_t(i \sim l) * P_t(l \sim m) * P_t(m \sim k) + P_t(i \sim j) * P_t(j \sim k)$$

Since this is a probabilistic framework, there is always a chance (perhaps vanishingly small) of transmission occurring via some roundabout path within the finite time period under consideration. This means that in order to determine an exact solution for the transmission probability, it would be necessary to compute $\mathbf{P_{sum}(i \sim k)}$, the sum of the transmission probabilities of all possible chains connecting **i** and **k**.

Initially it appears that the process would be similar to a Markov transition matrix and the transmission probability distribution could be calculated by taking very large powers of the matrix. However, there are several properties of information transmission which appear to violate the assumptions necessary for a Markov process. For one, information is not conservative: when it is transmitted from **i** to **j**, **i** doesn't usually lose the information. Second, there is generally a probability of **i** forgetting an item (an absorbing state in Markov terms), and also a probability of **j** "figuring it out" or discovering it independently without being directly informed (a generative state). Third, there is the question of what happens if an individual receives an item a second time. Does the confirmation of the initial message increase the probability of telling others, or will the probabilities decrease because the individual assumes that the message is now common knowledge?

Probably the answer depends on the kind of message in question. "Cultural" elements may behave in one fashion and gossip in another. This is a considerable obstacle for any attempt to construct a unifying model. Whether or not the model is analytically tractable depends on the matrix properties of the model - whether or not rows and columns sum to unity, the existence of disconnected components, etc. There are several features which would be expected in a "realistic" model. The initial behavior should be highly dependent on the starting conditions, but the long term behavior ought to be relatively stable, with the distribution approaching some limiting configuration. Ideally, the sum-of-all paths problem for the matrix could be solved analytically, and the resulting matrix could be multiplied by the

vector of in-the-know individuals, to yield a vector giving the probabilities of who is likely to know it in the next time step. Even if the exact solution cannot be determined analytically, it may be possible to arrive at a numerical approximation with an iterative calculation, taking advantage of the fact that the transmission probabilities for very long chains becoming vanishingly small, so the effects could perhaps be truncated after a certain range. Alternatively, an approximation could be calculated as a stochastic process by using the probabilities in the contact network to simulate a large number of interactions in order to observe the resulting distribution of the message.

There are many factors which would seem to make this formulation relatively impractical for more than toy models. One of the main points I've been trying to make in this paper is that the contact and transmission probabilities between pairs are NOT static, but are in fact quite time and context dependent. How would the distributions be calculated if there are multiple items in the system simultaneously? Furthermore, many of the bias effects described by Campbell (1958) could result in conditional probability relations between items, meaning that receiving one item could alter the probability of successfully receiving another, and the probability sums would become far more complex. $\mathbf{P_t(i\sim j)}$ is intended to represent the pair-wise transmission probability for one "item" given its associated context networks. As the context networks for different items are not likely to be the same, it is difficult to imagine how one might go about empirically determining values for all of the $\mathbf{P_t(i\sim j)}$'s in a network.

It seems worthwhile to "jump up" a level and consider again only the network of contact probabilities rather than transmission probabilities. I suggested earlier that the pair-wise contact probabilities, $\mathbf{P_c(i\sim j)}$ are conceptually equivalent to a sum of all the various structural "driving" networks, and that they are at least hypothetically observable. The two kinds of probabilities could be related by considering contact to be an upper bound on transmission:

$$\mathbf{P_t(i\sim j) > P_t(i\sim j)}$$

This means that if sufficiently detailed data on the interaction between group members could be

collected, these values of $\mathbf{P_c(i\sim j)}$ could be used to estimate a "maximum" probable distribution of information, and, as much as the network is stable, project a short distance into the future.

Another possible way of looking at the temporal evolution of the problem is to make the (unreasonable) assumption that pair probabilities are relatively static and ignore the contributions of the other possible paths in the network. Then, since $\mathbf{P_t(i\sim j)}$ is the probability of transmission in one time step, the probability of transmission having occurred after n steps would be:

$$\mathbf{1-(1-P_t(i\sim j))^n}$$

Although $\mathbf{P_t(i\sim j)}$ originally represented probability of transmission in unit time, it could be reconceptualized as $\mathbf{P'_t(i\sim j)}$, where one interaction "generated" by $\mathbf{P_c(i\sim j)}$ transmission various nodes could be calculated according to $\mathbf{Pc(i\sim j)*(1-(1-P_t(i\sim j))^n)}$ Further analytical work is needed to determine whether this equation would be at all meaningful when the whole transmission matrix is considered simultaneously. In other words, does $\mathbf{1-(1-P_{sum}(i\sim j))^n}$ accurately describe the probability of transmission between a pair in a matrix after n time steps, or do the probabilities need to be summed in alternative fashion? But again, in many "natural" social situations it seems $\mathbf{P_c(i\sim j)}$ would be fairly unstable. These changes are brought about by all of the unknown "group dynamics" effects, including some of the culture and information effects discussed earlier.

If some of the generalized patterns of group dynamics could be expressed in this sort of probabilistic network terminology, it might be possible to code them into a theoretical model to make possible qualitative estimates of future states of contact distribution for a network, and the contact distribution could be used to obtain an impression of information distributions. This is essentially the approach taken by Snijders and his collegues in their "Stochastic Actor Oriented Networks Models" (Snijders & Marijtje 1997, Snijders 2001a) but their emphasis is more on estimating the magnitude of various network functions in observational data collected at several time points. However, because their approach is to run the models as a simulation

and quantitatively compare the resulting networks to observed social networks, their algorithms can also be used as a generalized model for social network construction and dynamics.

Skyrms and Pemantle (2000) examine the dynamics of a very simple model of the formation of social interaction networks. In their simplest setup, agents start out with equally weighted probabilities of "visiting" each other and these weights are incremented after each successful visit. Even this simple model is sufficient to generate some degree of "structure" in the relations as initial random perturbations are magnified through later interactions. One of their slightly more complex models incremented the interactions weights for both the visitor and visited. This is in many ways analogous to a model that could be created by assuming that cultural exchange between the actors leads to increased similarity and future interaction. Later developments of Skyrms and Pemantle's models add discounting of past interactions, noise, or game-theoretic interactions between the actors. Not surprisingly, the results are difficult to summarize succinctly. However, one result was that in many situations in which the limiting configuration was empirically derivable, the networks often took a great deal of time to converge. And the addition of discounting and noise generally resulted in the network's eventual convergence on sets of dyads, or occasionally stars.

An interesting question which was not within the scope of Skyrms and Pemantle's (2000) paper is what happens when the interactions take place in sets larger than dyads. This is partially a question of the level of analysis. Although it may be possible, by looking at extremely fine time scales, to break apart any relations between groups into sets of dyadic interactions, it seems that some situations might be better described as sets of simultaneous relations. When a lecturer addresses a crowd, for example, everyone may be receiving roughly the same information or degree of contact. Or when groups of friends meet and participate in joint interactions - one common dinner table conversation - the "bond" that is reinforced may be among all of the members of the group as whole, and might not apply in the same fashion to individual pairings in other contexts. In many social media (email and phones perhaps being

an exception) interaction between pairs of individuals are generally not isolated and independent. Interactions are often visible to others individuals[16], and can occur simultaneously. Individuals often act to "catalyze" interaction between mutually unacquainted friends- either intentionally through social events, or coincidentally due to overlapping visits.

This is actually part of the discussion of the small world problem. To what degree is the likelihood of two individuals meeting determined by the number of friends they have in common? Jin and Newman (2000) develop an interaction based friendship network dynamics model which allows for transitive friendship effects, as well as saturation effects due to the assumption that a person has only a finite amount of time available for maintaining relationships. (A person cannot have more than a certain number of friends and acquaintances) In the most basic version of their model, actors were selected randomly to interact with a probability proportionate to the length of time since their last interaction. Initial analysis of the model shows that it is quite capable of generating networks with properties (clustering coefficient and characteristic path length) similar to observed networks.

If modeling is intended to represent process which could occur in actual social networks, it seems important to include, as these models do, the possibility of noise and randomness. In the real world, even if two individuals are not connected (or perhaps connected by very long acquaintance chains) there is still a small probability of them interacting through happenstance - non-socially mediated random encounters. The chance of this kind of encounter could be fairly high in some situations - in a interactionaly dense and spatially overlapping setting like a college campus, for example. Also, this noise term can serve as catch-all for all the non-correlated parameters which are not included in the model. Noise in a model gives the connections some freedom to "random walk" so that the network would be gradually but continuously shifting. The interplay between noise and structural effects can be complex.

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[16] This creates many fascinating sociological phenomna like the "multiple audience" situation in which a person must convey two differnt things to diffent groups at the same time with a single set of actions. Also "triad closure" or "balance theory": If I discover that a person I like is friends with a person I dislike, to function socially I may either have to terminate the first freindship or initiate a friendship with the person I dislike.

Random connection changes could establish links to isolates and to sections of the network which were disconnected in the initial condition, but if random effects are very large, they will likely wipe out most of the structure and result in a fairly homogenous network. (Jin & Newmen 2000)

It is probably important to stop and rephrase this discussion in more social terms. The kind of model I'm interested in investigating describes a situation in which a group of actors start out with some initial distribution of contact frequencies. They all go around looking for people to bump into, based on who they remember interacting with before, with the addition of some slight bias due to demographic variables and spatial effects. When one or more people interact (overlapping bumps), they all remember the interaction and forget all their previous interactions a little bit. If one group ends up bumping a lot, they may remember each other so much that they forget the people they used to bump into. "History" or "memory" parameters control how forgetful people are, and the randomness parameter controls how often they "randomly" bump into each other.[17]

This model can be extended in several ways to make it more realistic. For one, it is important to consider the initial setup of the probabilities at time zero. A fair amount of the dynamics may depend on this initial configuration. This initial matrix can be viewed as coding in some of the structural and attractive parameters of the actors in the network based on the structural relations between them due to the environment, role embeddedness, etc. For example, at Bennington College it may be that individuals who share a house or are in the same course have much higher interaction probabilities simply because they often occupy the same physical space. A constant value could be added to the weights of the connections between individual in the same house. If charisma and sociability are shown to have an effect on tie

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[17] When I say that individuals or networks "remember" or "forget," I do not mean that they forget a person the same way one might forget a phone number. Each person does not neeed to explicitly rembember a larger number of past states. The type of memory I'm referring to is more along the lines of the dynamical systems concept of the number of states back in time which must be taken into account in predicting the next state. In other words, if where I sit in the dinning hall is completely random, there is no memory effect from where I sat in previous meals. If where I sit today is strongly influenced by where I sat yesterday, then there is some degree of memory in my seating choices. If where I sit today is influenced by where I sat yesterday as well as where I have been sitting for the last four years, then the system has a strong memory.

generation, a value could be added to the probability of forming connections to the popular people. In Snijders' model, this was accounted for by allowing the attributes of each actor to impact their "network attractiveness". (Snijders 2000a) It seems consistent with my personal experience that individuals preferentially associate with others who are "culturally similar" to themselves. If actors participating in an interaction do transmit and exchange "cultural material" or information, it is likely that they would leave the encounter in some way "more similar" than they were before-hand, and that this might mean an increased likelihood of future interaction. So information transmission would "feed back" into the network formation process. But it is difficult to say what the magnitude of this effect is in comparison with, or how it is related to, all of the many complex "psychological" variables of attraction or strategic choices on the part of actors. A crucial step towards becoming clearer about what kinds of models are appropriate would be to get more information on the processes as they occur in the real world. If high quality data could be simultaneously collected on the network dynamics, information transmission, and demographic variables of a large community, it could go a long way toward answering some of these questions.

## IX. Bennnington Social Network Study

At the same time that I've been doing the literature research for this project, I've also been conducting a short term longitudinal study of social and informational networks as they develop among the entering first-year students of the Class of '04 and the rest of the Bennington College community. I had several reasons for wanting to do this. Throughout this work I have

been discussing and suggesting conceptual frameworks for thinking about information in social networks. My hope was that doing this kind of study might give me some real data for comparison - a qualitative check on how well theory actually describes what is going on. Ideally a network study of the campus might give me a baseline idea of the social structure of Bennington which could be built upon in future work. At the very least, attempting to construct and implement a study would teach me a great deal about methodologies and the complicating factors which will inevitably crop up when dealing with theory and data in the real world.

The Bennington College community and the entering class are an interesting subject for several reasons. For one, Bennington College is small enough that most of its members are known to each other (although that may be changing somewhat as the size of the student body increases). It is also in a sense fairly well bounded - there are formal categories of institutional membership as well as a strong consensus on who is part of the community. Although this certainly doesn't eliminate the important theoretical problems of defining the boundaries of a social group, there is at least a relatively unambiguous operational definition of membership.

But my intuition is that the students here would show up as a "distinct social group" under a wide variety of definitions. The Bennington student community seems to display an unusual degree of isolation. Nearly all the students live in campus housing, the campus is located outside the town of Bennington, the majority of social activity takes place on campus - it is rare for students to hang out in off-campus bars, etc. Many students do not own vehicles, and there seems to be a strong tendency for them to remain on campus for large segments of the 14 week term. When there is contact with individuals in the surrounding community, it is usually of a functional rather than social nature - interactions with clerks at the grocery and liquor stores for example. Furthermore, nearly all of the students are on the College meal plan, and eat three meals a day together in the same dining hall. All of these factors argue for a situation in which a huge proportion of students' interactions will be with other members of the

college community[18]. Another advantage of Bennington is that the size of the College is small enough that some of the comprehensive survey methods for investigating social structure are quite feasible. At the beginning of the term in which I conducted the study, the number of registered students was 545, including a total of 28 in the MFA, MAT, and Post-Bac programs.

The event of a new class entering is also interesting for several sociological reasons. Most entering students arrive at Bennington (or any college) knowing almost none of their new peers. Furthermore, they are usually separated from their original (home) community social connections to a large degree. Although accepted as perfectly normal, this situation is pretty unusual. For most of us, arriving at college is one of the few times in our lives when we are able to construct an entire social network entirely from scratch, free from the direct influences of our parents and our social history. Perhaps this is part of what makes college such an exciting and scary experience. As I mentioned in the section on social networks, it is often the case that people meet others through people that they already know, creating an overlapping network of friend's friends. But students arriving at Bennington come from communities all over the world, and may not have any second-step social ties in common with their new peers (this in itself is an interesting question to investigate.) Yet despite all of this, people seem to establish themselves and become oriented and connected very quickly. This makes the entry into college a fairly unique opportunity to track the growth and spread of social structure - provided an appropriate methodology can be developed.

Aside from an academic interest in the process of network formation and information transmission, I'm also curious about what it might say about Bennington in particular. How quickly and thoroughly are the freshmen integrated into the 'culture' of the school? How "cliquey" is Bennington? How does the social structure evolve over time? Do contacts made in orientation groups persist? Are houses or hobbies more important in determining who people socialize with? What demographic variables are predictive? It is hard to imagine that any

[18] The age stratification present in most institutions is clearly present here as well. Although Bennington does have a few older students as well as a BA/MAT program and an MFA program, the vast majority of the are 18-22 years old.

kind of study could provide definitive answers about a place as diverse and rapidly changing as Bennington, but looking at these kinds of questions with some objective data is likely to provide some interesting insights.

But I'm especially interested in trying to examine the structure of the communicative networks among community members. Do people's self descriptions of who they talk with and get information from reflect the "collective" conception of the organizational structure, or are they independent of it? How well integrated are "official" information channels (House Chairs, various administrative offices) into the actual network of people to whom we go to with questions? Are there "central" individuals who everyone knows and talks to? Who are they? Are there aspects of the geometrical structure of social connections which might give clues about the institution's quirkiness?

My plan was to administer a social network survey to all of the first year students three times during their first term at Bennington. The first would hopefully take place as close as possible to the beginning of term (within the first couple of days) and the last would take place towards the end of term. The survey would take advantage of the known-membership aspect of Bennington. Each first-year would be given a multi-part, random-ordered list of everyone at Bennington, including faculty, administration, and upperclassmen (600-700 items) They would first be asked to indicate all of the names on the list which they recognized. Withen this subset they would be asked to indicate people with whom they have spoken.. This would be repeated, with questions asking about weekly and daily conversations. The survey would also collect some demographic information.

Obviously, the demons are in the details, and many of the specifics changed as I began dealing with the various technicalities and practicalities of implementing the study. To facilitate collection and the on-the-fly generation of the random name lists and the subsets which are specific to each person, I decided to make the survey questionnaire computer based, accessible as a JavaScript program running on a web site. One advantage about doing a web-based survey is that respondents can be simultaneous or asynchronous, so I wouldn't need to

worry about coordinating schedules. It also meant that I could collect some temporal data as well. But I was also concerned that I might get a fairly low response rate because the medium might be unfamiliar to some, and I was asking people to do the survey on their own time. I decided that I would initially notify people with a letter, and follow up with phone calls to non-respondents. The admissions office kindly agreed to distribute a letter containing a brief description and the web address for the study to each of the 1st-year's mailboxes.

The survey was structured as follows: The Dean's office provided me with a list of all the currently enrolled students and their class status.[19] Each of the names was assigned a unique study-specific ID number. I included in the survey all of the incoming freshmen (167 names, class status of 0) and a randomly chosen sub-sample of the upperclassmen (73 names, or ~%20). I also included 10 names (chosen at random from an email petition) that were not members of the Bennington community to use as a control. There are obvious disadvantages to using only a sub-sample of upperclassmen and eliminating the faculty and administration names from the study, but the 250-item survey I used took ~10 minutes to complete and I was concerned that any additional names would increase non-response due to fatigue and boredom.

Upon logging onto the study site, respondents were shown a brief description and explanation of the study, presented with a link to obtain more information, and given the following instructions:

> This survey is one of a class of surveys called Network Name Generators. I have implemented it as a web page to try to make it simpler, faster, and easier for both you and me.
>
> Please keep in mind that,
> - You will not be asked to provide any sensitive information.
> - The information you provide is for the purpose of this study only and will be kept confidential.
> - Your name will not appear in any paper or report, unless you give me explicit permission to use it
>
> The survey is divided into five sections:
> The first asks for fairly standard background information, such as your name and age, but also for information on what house you live in and what classes you are

[19] I discovered later (I was informed by respondents) that at least two of the names on the list given to me by the Dean's office contained misspellings. This does present a problem, but both names were distinctive enough that they are unlikely to have been confused with other individuals.

taking. You will be asked to provide contact information (phone or email). This is in case you do not complete part of the survey, or I need to contact you with questions.

The second part of the survey is the longest. A very large number of names will appear on screen one at a time. For each name you will be asked to click a button indicating whether the name is familiar to you. There are 250+ names, so you will want to work as quickly as possible. If you make a mistake, you can use the "GO BACK" button to return to the name and make the correction.

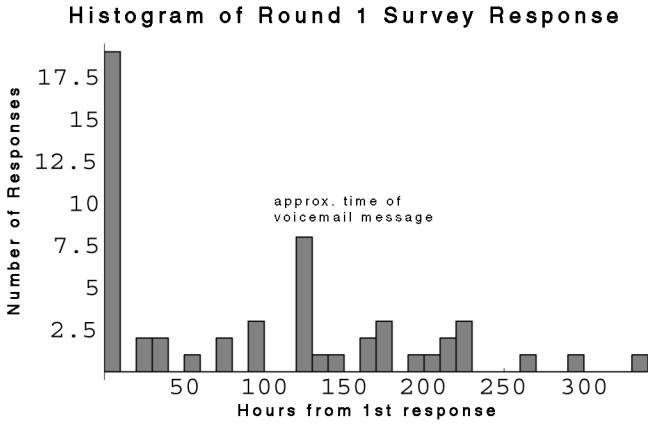
The third and fourth sections are very similar and will not take nearly as long (depending on how many names you are familiar with). All of the names which were familiar to you in Part II will appear in random order, and you will be asked how often you have conversations with each person.

Finally, you will be given a chance to comment on the survey and provide some suggestions.

If you are ready to begin the survey, please click the link below. Otherwise, please contact Skye Bender-deMoll with questions or concerns. [phone: x4110 email: skyebend@bennington.edu]

If the respondent clicked the link labeled "I have read the instructions and give permission for my information to be used in this study," they were taken to a page containing a form for entering demographic information. When that was completed, they were taken through the name recognition process as described in the instructions. Upon completion they were thanked, and the formatted data from the survey, including a time stamp and other data, was automatically emailed to me.

The first round of the study began on September 12, about two weeks after the freshmen arrived on campus for orientation. The Admissions Office placed the memo in the freshmen's boxes by lunch time. At 4:30 I received a call from a student who was unable to complete the survey on his computer. It turned out that there is a bug in Microsoft Internet Explorer 4.5 which prevented the survey from working. This is one of the major problems of attempting sociological research using the web. It is very difficult to allow for all possible configurations of browsers and platforms, or to determine where technical difficulties have affected responses. These kinds of problems were recurrent throughout the study. At several points in time, the College-operated server on which the survey resided experienced technical problems which prevented people from accessing it. (This did result in one humorous response in which a student who had been unable to connect contacted me and mentioned the possibility that *really* I was conducting a study to see how many people would call to tell me that it didn't work! - he must have been



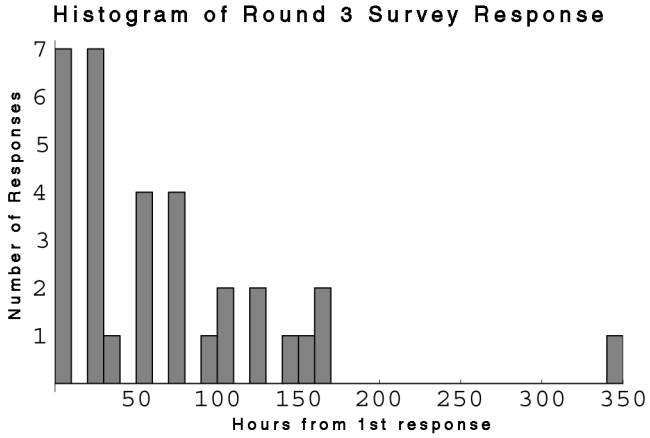
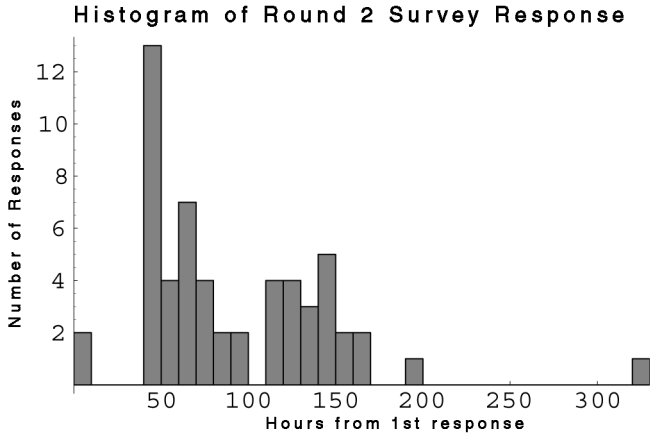




Fig. 18 Histograms show the patterns of survey responses for each of the three survey waves. The second peak in the first graph corresponds to the time block immediately following the telephone request.




taking a social psychology

class.)

One week after the initial notification I had received ~30 responses. At 5 p.m. on September 17, I sent a voice mail message to all the first-years who had not responded. The message re-informed them of the study, provided them with the web address, and stressed the personal favor aspect of completing the survey. As Fig. 18 shows, this resulted in an immediate jump in responses. It is interesting that throughout the study, response to the survey was characterized by this kind of near-immediate reaction to the "stimulus" of the request, followed by a long gradually decreasing tail. It is important to remember that the networks generated by the three "rounds" of this study are aggregates formed by a fairly arbitrary collapse of the temporal data. Some of the outlying points of Round I are actually much closer in time to the start of Round II. In a sense, these data shouldn't really be considered as a "snapshot" of the network at all. The data which I collected using this methodology should be thought of as a collection of self-reported subjective ego networks with specific locations in time. But most types of analysis will require some sort of segmentation into a collective network.

Responses to the first set of questions were based on name recognition. This might be considered a slightly more objective task then rating interaction frequencies, but it is certainly subject to error and bias. One problem which was frequently pointed out by respondents is that Bennington is a community where last names are rarely used, and this is especially true early in the acquaintanceship process. As one respondent put it:

> I personally have a problem with when filling out this survey is that I know almost nobody's last name. For instance, the name Jennifer. I know a few Jens, but not their last name, so I just don't click yes by these people. The people whose names there is only one of such as [unusualName] are different because it doesn't matter what their last name is, there's only one [unusualName].

I was aware that this might be a problem before the survey started. However, it seems likely that in ordinary situations the longer or "more deeply" two people know each other, the more likely it is they will know each other's last names. The exception to this would be various types of "celebrity" effects, where people's names might be well known outside of their actual acquaintance networks. There may also be effects of name "memorability" - some names, or

some people, may be more unusual or striking, and therefore easier to remember. The questions about conversational frequency are somewhat problematic as well. Respondents may have difficulty accurately recalling people with whom they had interacted.

One potential solution would be to ask a more specific question: "Who did you have conversation with today." However, to get a picture of more long term contacts, the survey would have to be repeated multiple times. Furthermore, the network survey literature suggests that even when asked questions about specific instances, people tend to respond with their "typical" interactants (Ferligoj & Hlebec, 1999, Marsden, 1990, ) The definition of "conversation" in the prompting question is somewhat ambiguous as well. I was reluctant to use a more specific definition of interaction because it might make the evaluative task more difficult, or potentially exclude some relations. For me, the definition of conversation would include very brief interactions but probably not passing greetings. It is likely that some respondents interpreted "conversation" in different ways, and their interpretation may change as they take the survey. I do not see any way to control for these kinds of effects for self report data. The only solution is to assume that the interpretations will deviate randomly, and to hope that there is no systematic bias in the responses.

**Analysis of the Survey Data**

Response to the survey was not overwhelming. The first wave contains 53 freshmen - roughly 32% of the class. The second wave has 55 names, and the third has only 32. A total of 76 people took the survey, but I only have complete data (all three waves and target information) for 22 people. One minor complication is that ~6 freshmen whose names were not on the target list responded, so I have no information on indegree (incoming connections) for them.

An immediate question which arises is how representative of the actual Bennington population these data are. Twenty-three percent of respondents indicated that they were male. Although this sex ratio might seem unusual, it is fairly close to the ratio on campus.

Nearly all Bennington students live in on-campus dorms or "houses" of 25-30 people, each of which has specific designation concerning issues like smoking and quiet hours, as well as a what is frequently referred to as a "personality." Residents from all of the 15 houses responded to the survey, but some houses appear to be over-represented. This is more of a problem in the set of 22 respondents who completed all three surveys, as many of the houses drop out completely. It is unclear how this might affect the results of various analyses.

It is also important to consider whether the respondents were treating the survey seriously or were simply clicking through the survey and selecting names at random. The 10 "dummy" names in the survey act as a useful control. The mean indegree score for the name recognition of the dummies (mean number of respondents who indicated that they recognized dummy names) can be compared to the indegree scores for the rest of the "genuine" target names. If the mean for the dummies is significantly lower, perhaps approaching zero, this would indicate that the respondents are at least "separating out" the dummies, and would suggest that they may be attempting to evaluate the rest of the names as well. As Figure 19 shows, this appears to be the case. In all three networks of all waves, the indegree of the dummies is very close to zero and significantly different (two-tailed t-test, $p < 0.001$) from the other classes. Furthermore, not one of the 76 respondents ever indicated an "at least daily" conversation with one of the dummy names.

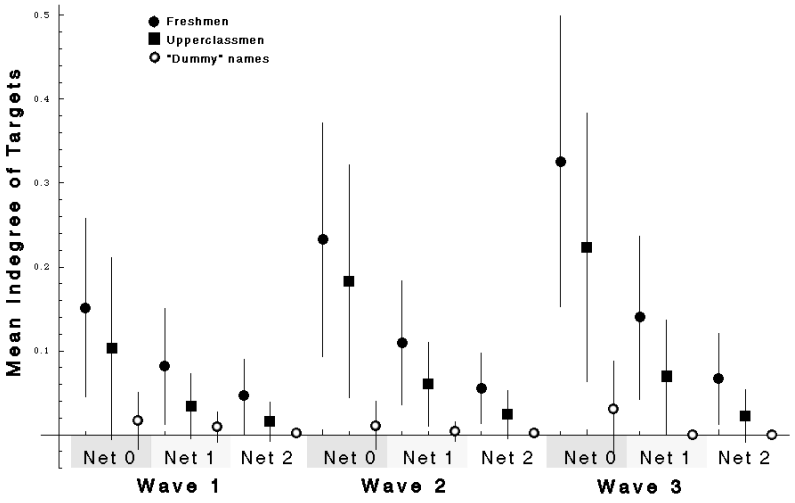



Fig. 19 Plot shows the mean indegree for different target categories. Lines indicate one standard deviation. According to a two-tailed t-test, the freshmen and dummy means are significantly different at the $p < 0.0001$ level. Upperclass and dummy means are significantly different ($p < 0.0001$), except for nets 1 and 2 in wave 1. For Net 1 and 2, freshmen and upperclass means are different at ($p < 0.001$), Net 0 is not significant for wave 2.

The analysis and discussion of these network data are complicated somewhat by their multiplicity. Because I collected network data from each respondent on three different questions, I essentially have three networks describing the respondent's relationships: Net 0 describes the names they recognize, Net 1 contains the target individuals with whom they claim to have "at least weekly" conversations, and Net 2 contains the targets with whom they claim to have "at least daily" conversations. However, because I shortened the survey with the subset design, the networks are not independent. That is, Net 2 can only contain individuals included in Net 1, and Net 1 can only contain individuals recognized in Net 2. In addition, most of the tests and computational tools for dealing with network data work only with square matrices. Because I did not collect data from the upperclassmen, and because may of the freshmen didn't complete the survey, a great deal of data must be "discarded" for some of the analyses. Many of the questions require different kinds of data, so, in an attempt to maximize sample size, I tried to use the largest possible data set appropriate for each question. In other words, care must be taken in comparing the analysis for different questions, as the data may not be literally describing the same network - even if the samples are drawn from the same theoretical Bennington network "population."

Because this analysis is intended to focus on the formation of social networks involving the members of the incoming class, it seems appropriate to examine the networks for changes in size over time. There are many possible ways of generating a size statistic with whcih to make comparisons. The network data in this study are fairly unusual in that each respondent completed the survey at a different time, so there is a large set of "ego" networks, each with an associated time. Although the size and structure of each individual's networks will be different, if the overall social network is in the process of formation, a general increase in the number of ties named by each respondent might be expected as time goes on. I examined the relationship between time and the average number of ties indicated by each actor (mean outdegree) with a regression analysis.

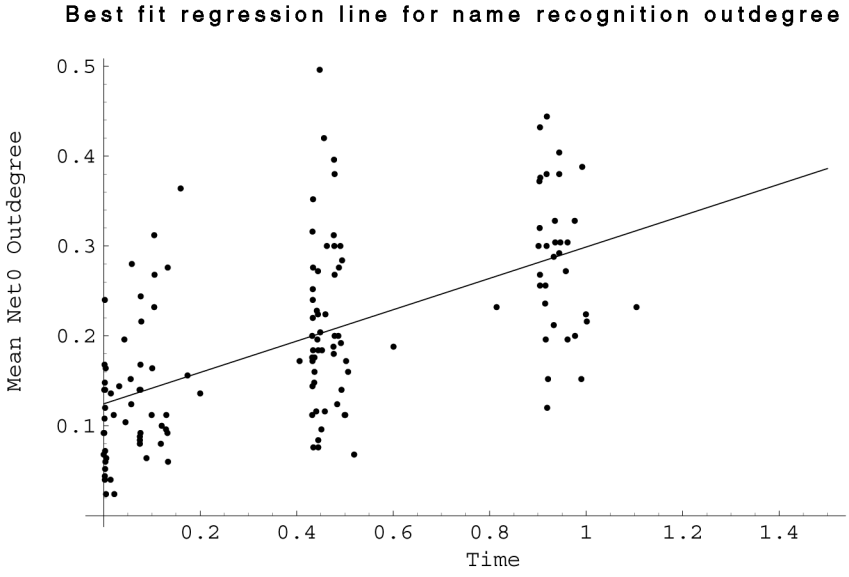



Fig. 20 Plot of mean Net 0 outdegree for each respondent by rescaled date of survey completion for all three waves. Line is best fit function from regression analysis.

As Figures 20-22 demonstrate, the distribution of outdegrees is quite large, and there is a fair degree of "clumpiness" in the temporal data because the bulk of the respondents completed the survey within the first couple of days of each wave. Even so, there appears to be a strong and highly significant increase with time. The line of best fit is approximately 0.12 +0.17 t, with an R-squared of 0.34 and significance (probability of obtaining as good a fit with a random distribution of points) of $< 0.001$. Although it would be quite difficult to extrapolate out of the sample to estimate a rate curve for the freshmen acquaintance process, it is

worthwhile to note that an extrapolation of the curve back in time would give an outdegree value greater than zero before the freshmen arrived on campus. This could mean that students are already familiar with some names when they arrive, (from campus visits, literature, etc.) and/or that the rate of name acquisition changes with time. It seems likely that rates of name acquisition would in fact change noticeably over the course of the term and over a student's educational career. For one, the size of the community would act as a limiting upper threshold, although that would change every fall as a new class is admitted.

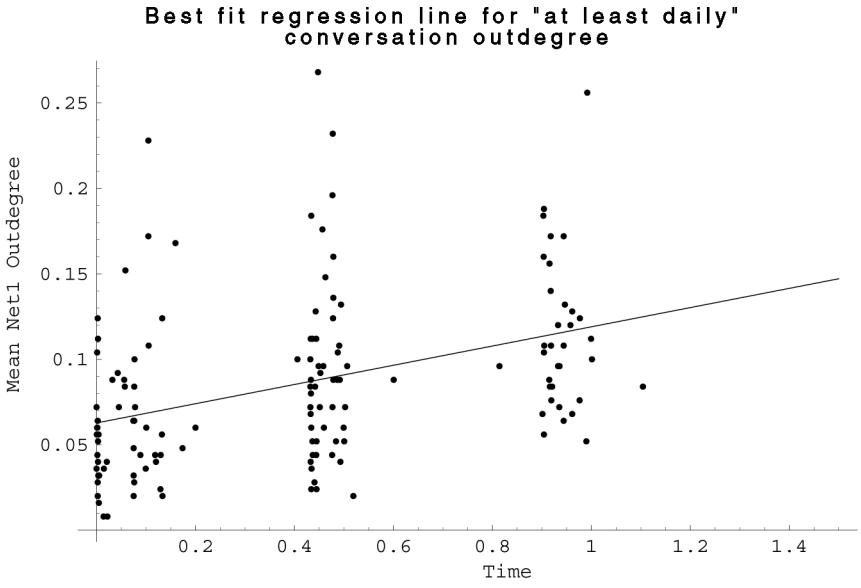



Fig. 21 Plot of mean Net 1 outdegree for each respondent by rescaled date of survey completion for all three waves. Line is best fit function from regression analysis.

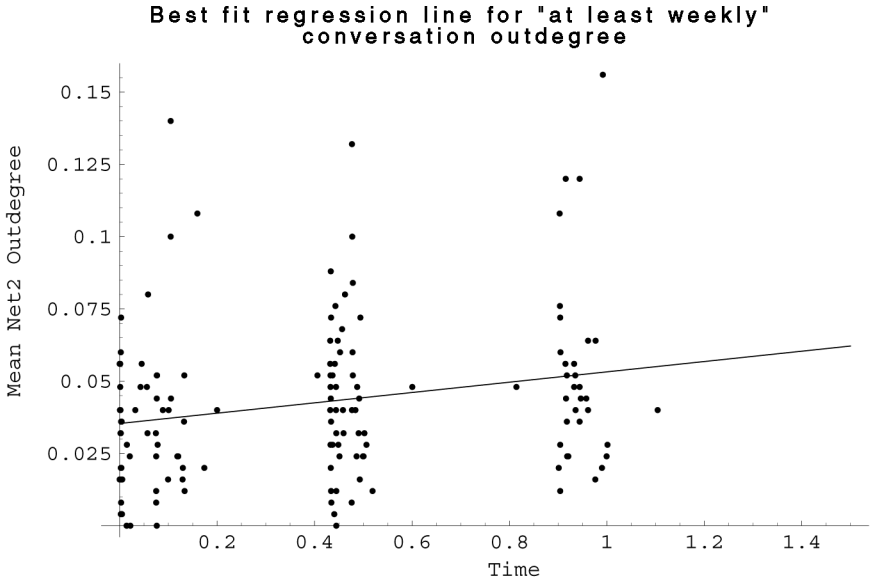



Fig. 22 Plot of mean Net 2 outdegree for each respondent by rescaled date of survey completion for all three waves. Line is best fit function from regression analysis.

I did similar regressions for the daily and weekly conversation outdegrees. (figures 21 and 22.) For weekly conversation, the fit was still significant with an R-squared of 0.15 and $p < 0.001$, but both the magnitude and slope of the best fit line are much less than was the case for name recognition.

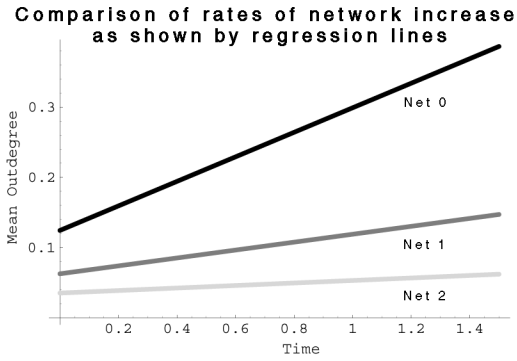



Fig. 23 Comparison of slopes of best fit regression lines for the three network information categories

The results for daily conversation are much smaller again, and the fit had an R-squared of 0.05 significant at $p < 0.01$. If the undersampling of the upperclassmen could be ignored and the results taken at face value, relationships between the fitted lines would indicate that freshmen converse weekly with about half the people whose names they recognize, and daily with about one fourth. However, name recognition continues to increase at a much greater rate than the interactional measures. This may be due to time limitation effects - a person can continue learning new names, but presumably they can only converse with a limited number of people in a given day[20] - although who the people are may change over time. A similar trend shows up when the data are aggregated into their collection waves and the matrix means (sum of all entries divided by the number) of each network are computed. The means for the matrices give essentially the same data that the regression does, just organized categorically rather then temporally.

[20] At one point during my Junior year, I attempted to log all of my interactions to get a very rough estimate of my own interaction density. The method was crude and I only managed to keep it up for for 2.5 days, but I ended up with an average of around 72 interactions with 40 people per day. However, it is difficult to make a comparison to the network data, as I was not a freshmen at the time and the sample period was so short.

| Means (density) of entire network matrices | Wave 1 | (N of Obs 13500) | Wave 2 | ( N of Obs 13750) | Wave 3 | (N of Obs 8250) |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD |
| Net 0 | 0.132 | 0.338 | 0.211 | 0.408 | 0.286 | 0.452 |
| Net 1 | 0.065 | 0.246 | 0.091 | 0.288 | 0.114 | 0.318 |
| Net 2 | 0.036 | 0.187 | 0.044 | 0.206 | 0.051 | 0.221 |

Table 1 Density scores and standard deviations for complete (all targets are included) raw network matrices

One question which is not well addressed by the regression plots is the relationship between the mean outdegree of the group and the trends for individuals. Are the outdegrees of all the individuals in the network changing systematically, or is the change due mostly to a few outliers? Figure 24 again shows plots of time of response against outdegree for every respondent. However, in these plots, individuals who appear in sequential waves are

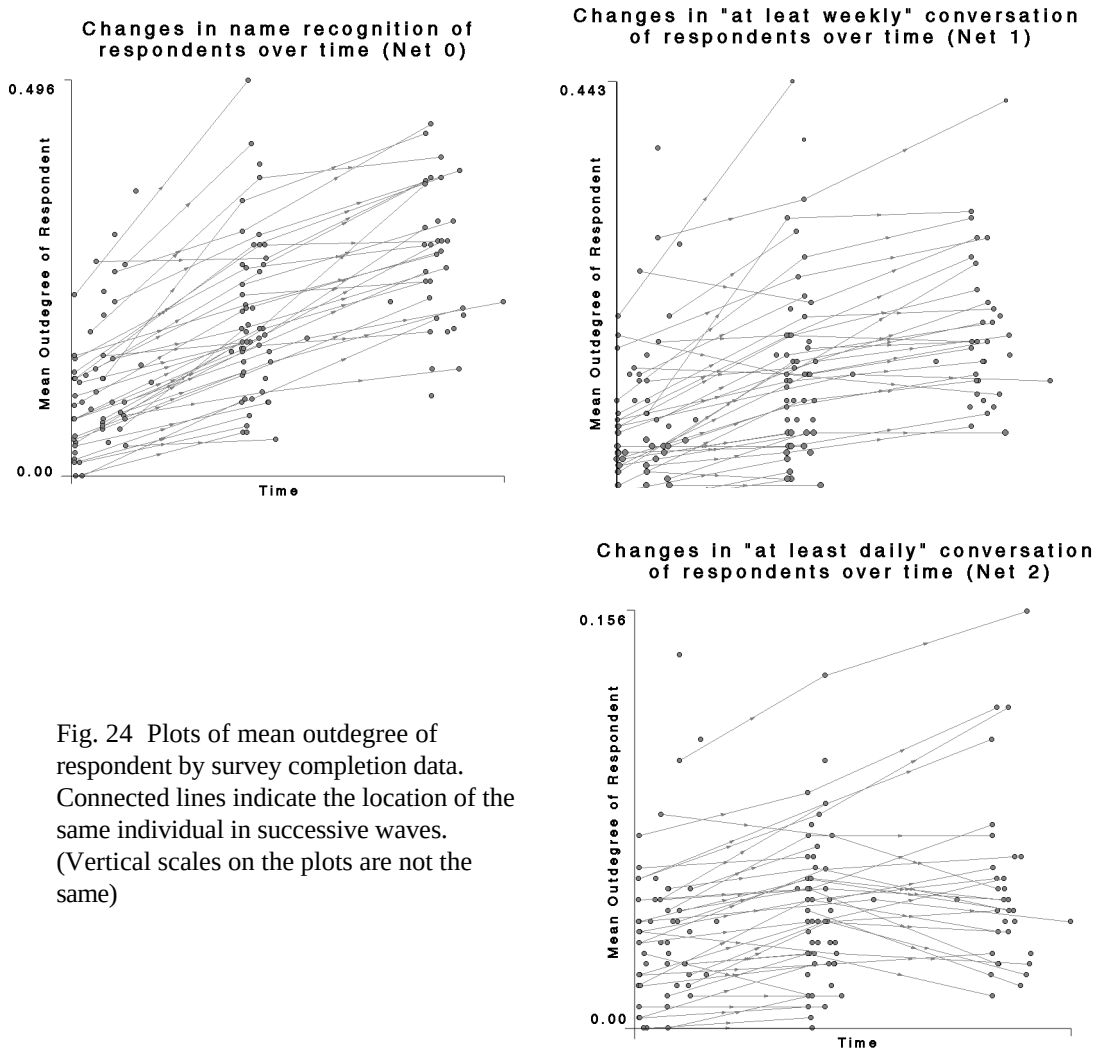



Fig. 24 Plots of mean outdegree of respondent by survey completion data. Connected lines indicate the location of the same individual in successive waves. (Vertical scales on the plots are not the same)

connected by directed lines. This makes the general trend appear even stronger, and also demonstrates a change of rates between the two time blocks. It is also clear that many individuals drop out in the third wave. Examination of the same kind of graph for Net 1 shows some interesting properties which were not apparent in the regression. Again, the overall number of connections in Net 1 is much smaller than in Net 0, but it is also clear that individuals are changing at different rates, and for most of them the increase between the 2nd and 3rd waves is negligible. Net 2 is even more striking. The "at least daily" conversation outdegree of many individuals actually decreases between the 2nd and 3rd waves. This, again, might be an effect of settling - perhaps after the initial flurry of meeting new people, students began to interact with smaller groups of friends.

It seems worthwhile to examine the relationship between the in and outdegrees for each individual. Figure 25 shows the indegree and outdegree values for individuals in the 22 x 22 matrices plotted against each other. In this kind of representation, people who have identical in- and outdegrees would appear along the diagonal. (The values for the in- and outdegrees used in this plot are the scores within the matrix, not the scores for the entire target list.) There do not seem to be any systematic trends other than those already mentioned. However, it is interesting that even for the graphs for daily interaction, where a fair amount of

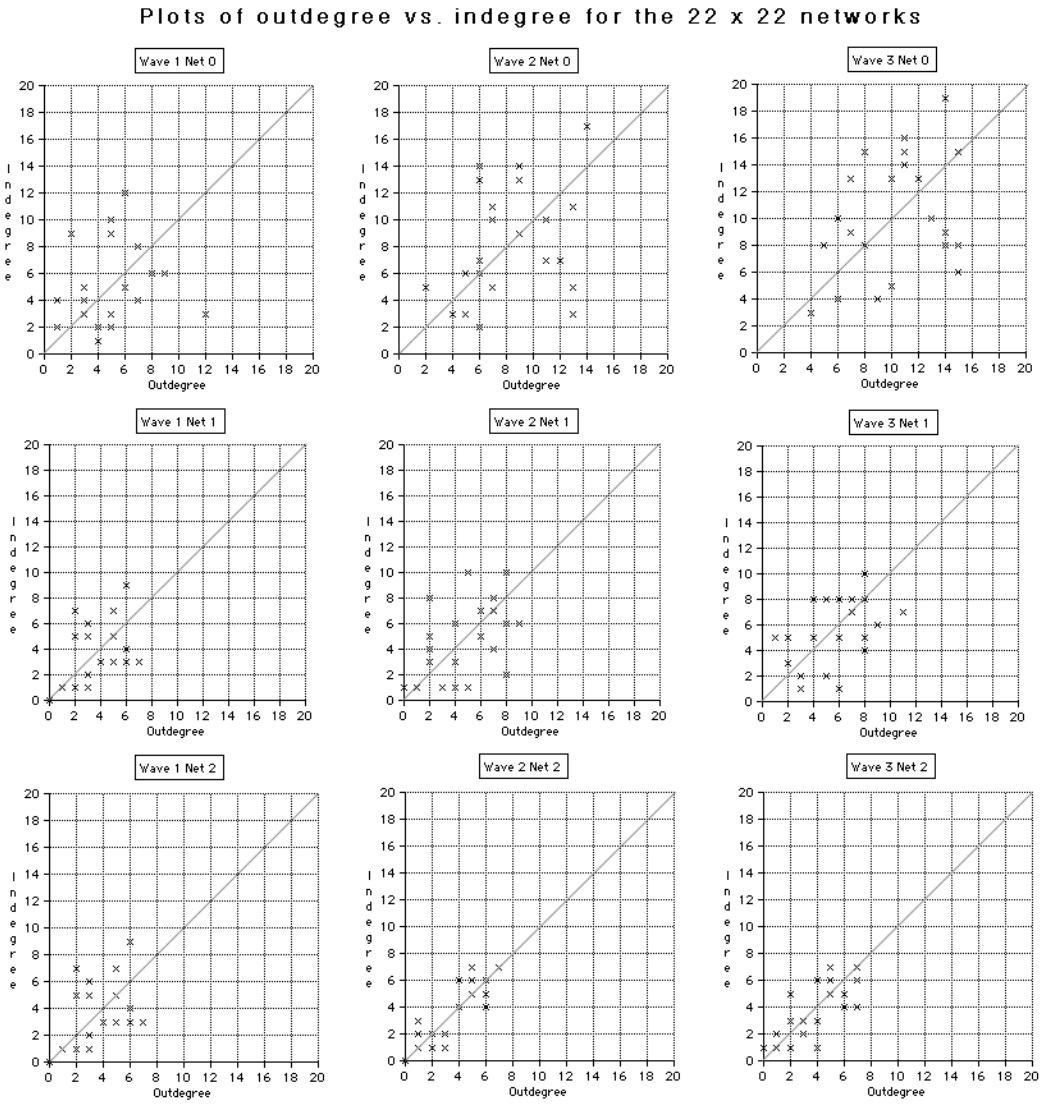



Fig. 25 Plots show the relationship between (raw) indegree and outdegree for the 22 respondents who completed all three surveys. Individuals who's in- and outdegrees are the same would appear along the diagonal.

agreement might be expected, there is still a noticeable discrepancy between in and out degrees. (Note that these graphs do not directly plot reciprocity because the identities of the in and out degrees are not taken into consideration.) There also may be a slight bi-modality, a segmentation into a high in- and outdegree group and a low group. This trend is also visible in Net 2 in Figure 24, but may simply be an artifact of the small 22 person sample.

The indegrees for all of the 250 targets considered together show the same trends as the outdegrees for all the respondents. To some extent they must do so because, they are extracted from the same matrix, but plotting the indegrees allows inspection of the trends for individuals as well. Figures 26, 27, and 28 show the same kind of information as Figure 24 - changes for each individual from one wave to the next - but in this case the number of individuals remains constant so the information can be presented as lagged plots. For each individual target, the mean indegree value for one wave is plotted on the horizontal axis and its value in the next wave is plotted on the vertical axis. As in the previous plots, individuals who show no change would appear on the diagonal. Although there are 250 points in each relation, many of the points in the plots for Net 1 and Net 2 overlap due to finite size effects. In all cases there are some individuals whose indegree decreases (plotted below the diagonal), but the majority increase (plotted above the diagonal). The largest outlier in the name recognition plot is actually me, as respondents probably had to see my name a large number of times during the survey process.

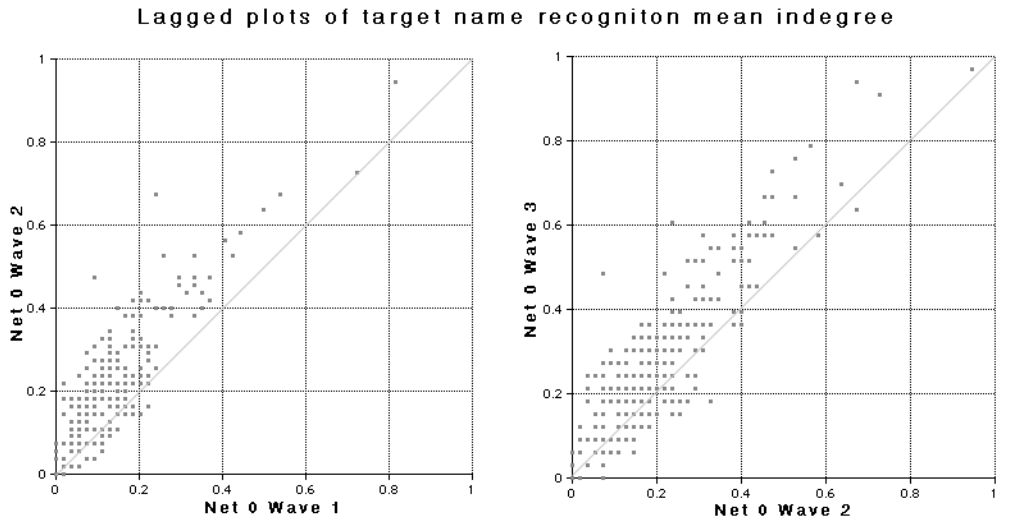



Fig. 26 Lagged plots show the relationship between indegrees in successive Waves for the 250 targets.

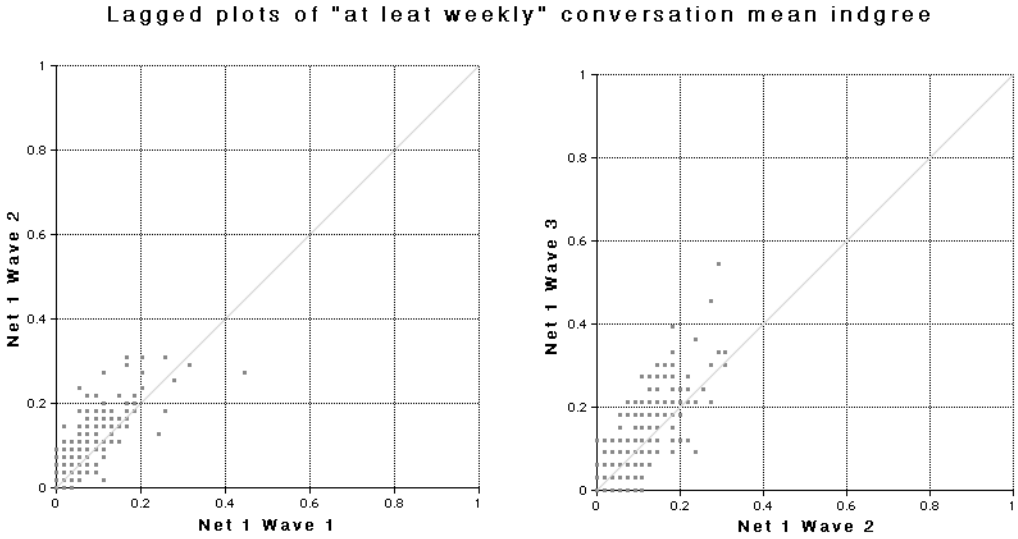



Fig. 27 Lagged plots show the relationship between indegrees in successive Waves for the 250 targets.

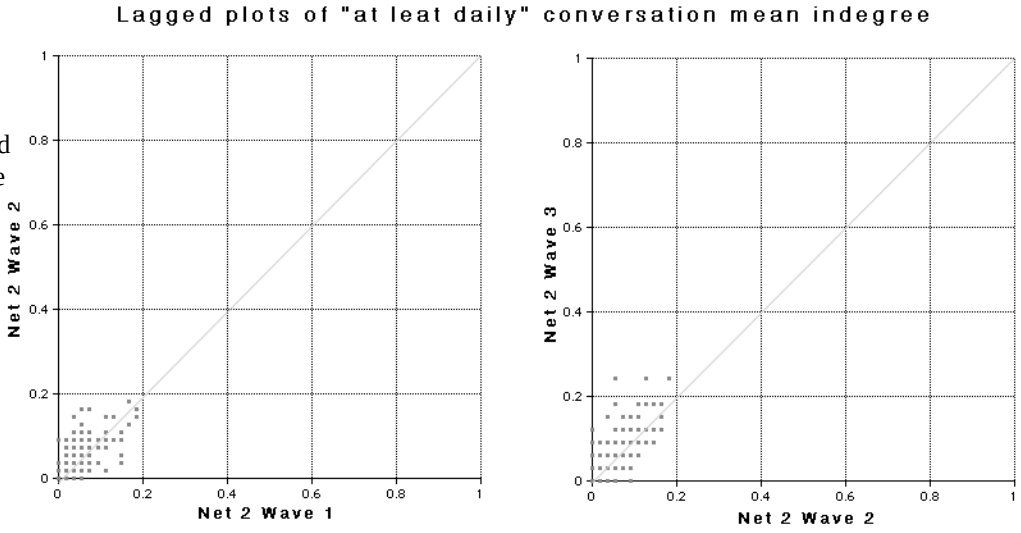



Fig. 28 Lagged plots show the relationship between indegrees in successive Waves for the 250 targets.

It is important to remember that the indegrees for both upper- and underclassmen are plotted together in these graphs, and that all of the values are from the perspective of the small group of freshmen respondents. There are, in fact, quite significant differences in the aggregate means of these categories. Figure 19 shows that throughout the study, the freshmen targets on average received greater numbers of recognitions and relations than the sample of upperclass targets did. Although this is not terribly surprising, as it seems consistent with my experience that the freshmen associate more with each other than with the upperclassmen, it does provide some evidence that, at least until the end of the term in which the study was carried out, there was a consistent degree of separation, or lack of integration, between the incoming freshmen and the upperclassmen. It would have been fascinating to repeat the survey at the end of the freshmen year to see if the segregation persists, or if the student body becomes more uniformly mixed.

If the network data collected in this study do in some way describe changes in social structure over time, it is likely that there will be correlations between the networks at subsequent times. The interval between the survey waves is small enough that the pattern of connections in one network matrix should be fairly predictive of the connections in the same matrix at the next point in time. In a sense, this is what the lagged plots show, except that they only compare the number of connections and not their actual pattern. The network analysis package UCINET (Borgatti, Everett, & Freemen, 1999) which I used for most of the analysis has a QAP Correlation procedure which I used to estimate the relationships between the networks. According to the UCINET documentation, QAP correlation first computes several standard measures of the correlation between the two (square) matrices, and then computes an estimate of the significance of the correlation by permuting the elements of the matrix a large number of times and counting the number of correlations which are larger or smaller.

I have some doubts about the appropriateness of the standard QAP procedure. Some of the assumptions which must be made about the network lead to overestimates of significance, but at the moment there is no real alternative. Because of the requirement that the matrices be

square, I used the 22 x 22 matrices of individuals who responded to all three waves, meaning that the patterns of connections to upperclassmen are not considered in this analysis, and that these results may not be typical of the overall sample. All significance estimates were made with 25000 permutations of the matrices, none of which resulted in correlations as large as the observed correlations, leading UCINET to give significance values of 0.000 for all correlations. This should be interpreted, with reservations, to mean that the following correlations are significant at the $p < 0.001$ level.

| **Net 0** | **Wave 1 to Wave 2** | **Wave 2 to Wave 3** |
|---|---|---|
| Pearson Correlation: | 0.56 | 0.718 |
| Simple Matching: | 0.795 | 0.855 |
| Jaccard Coefficient: | 0.49 | 0.706 |
| Goodman-Kruskal Gamma: | 0.922 | 0.965 |
| **Net 1** | | |
| Pearson Correlation: | 0.629 | 0.836 |
| Simple Matching: | 0.882 | 0.94 |
| Jaccard Coefficient: | 0.521 | 0.773 |
| Goodman-Kruskal Gamma: | 0.951 | 0.991 |
| **Net 2** | | |
| Pearson Correlation: | 0.665 | 0.86 |
| Simple Matching: | 0.913 | 0.963 |
| Jaccard Coefficient: | 0.558 | 0.788 |
| Goodman-Kruskal Gamma: | 0.958 | 0.994 |

Table 2 QAP matrix correlations from UCINET

Most of the correlation values are fairly large, indicating that the configuration of the network at one point in time is fairly dependent on its previous configuration - an outcome which would be unlikely if respondents were clicking through the survey at random. Although the different correlation measures emphasize different aspects of the relationships, the trends are consistent: the correlations increase from Net 0 to Net 1 to Net 2, and from the first time period to the second. This makes some sense when considered in light of the rate findings from the regression. Individuals are added to the interaction networks much more slowly than to the name recognition network, so the changes are less and the correlations should be higher. Table 3 presents a summary of the element-wise changes in the 22 x 22 matrixes from wave to wave.

| Net 0 | Wave 1 to Wave 2 | fraction of matrix | Wave 2 to Wave 3 | fraction of matrix |
|---|---|---|---|---|
| 0 -> 0 | 290 | 62.8% | 245 | 53% |
| 0 -> 1 | 86 | 18.6% | 56 | 12.1% |
| 1 -> 0 | 11 | 2.4% | 13 | 2.8% |
| 1 -> 1 | 75 | 16.2% | 148 | 32% |
| Hamming Distance | 97 | | 69 | |
| **Net 1** | | | | |
| 0 -> 0 | 363 | 78.6% | 354 | 76.6% |
| 0 -> 1 | 44 | 9.5% | 22 | 4.8% |
| 1 -> 0 | 13 | 2.8% | 7 | 1.5% |
| 1 -> 1 | 42 | 9.1% | 79 | 17.1% |
| Hamming Distance | 57 | | 29 | |
| **Net 2** | | | | |
| 0 -> 0 | 387 | 83.3% | 397 | 85.9% |
| 0 -> 1 | 22 | 4.8% | 10 | 2.2% |
| 1 -> 0 | 20 | 4.3% | 7 | 1.5% |
| 1 -> 1 | 33 | 7.1% | 48 | 10.4% |
| Hamming Distance | 42 | | 17 | |

Table 3 Changes in matrix elements (ignoring diagonal)

Surprisingly, there are quite a few names "forgotten" between the waves. Almost 13% of the names present in wave 1 are not present in wave 2. Although I expected some change in both directions in the conversation networks, the magnitude of name loss is unexpected, possibly indicating a fair amount of error in the data collection. It might also indicate increased ability on the part of the respondents to distinguish between the various target names. In other words, a respondent might have chosen more than one Sarah in the first round, but by the 2nd round the last names were familiar and it was possible to distinguish between them. The overall rates of change (Hamming Distance) are also much less in the 2nd time period. This may indicate some degree of "settling" of the network into stable configurations, or ceiling effects due to the limited population size. Again, this is difficult to tease apart for Net 1 and Net 2 because they are strict subsets of Net 0 - any names which are omitted in error from Net 0 must also be missing from 1 and 2 .

One of the main things which is interesting about these data are their evolution over time. But since the dimensionality of the data is so high (connections between a large number of individuals), there are only certain kinds of relationships that can be examined with traditional time-series techniques. One approach is to perform a set of operations on the network data in order to extract some aggregate measure or statistic, and then analyze the trajectory of this parameter over time, as in the network size example above. Another approach, recently developed by Tom Snijders, is to construct models of the entire network as a stochastic dynamical process, and analyze the properties of the models and their fit to the observed data. (Snijders 2001a, Snijders & van Duijn 1997)

One way to think about this is with an analogy to regression analysis. The basic idea in regression analysis is to determine a line or polynomial curve that "fits" the observed data with the least amount of error. In a sense the curve is a model for predicting the relationship between the dependent and independent variables, and the appropriateness of the model is evaluated by calculating some statistic describing the degree of error (un-explained variation) between the model and the observed data - the most commonly used statistic is RMS error.

In SIENA, Snijders' experimental network dynamics statistics package, the model is an algorithm for generating networks at successive points in time, and the statistics used for comparing the observed and predicted networks are various graph- and network-theoretic statistics: density, number of triads, etc. In traditional regression, the parameters control the relative effects of the polynomial terms of different degrees. In SIENA's algorithms, the parameters control the relative effects of the formal descriptions of various network processes: transitivity, reciprocity, density effects, etc. Although the specific assumptions of Snijders' "stochastic actor-oriented models for network evolution" are likely to be crucial in interpreting the results, I'm not going to discuss the details here. The basic idea is that the evolution of a sociomatrix can be modeled as continuous-time Markov chain Monte Carlo process. This is somewhat similar to model I discussed above. Snijders' perspective is more flexible and perhaps more "realistic" than previous approaches as it does not require dyad independence.

> The basic idea for our model for social network evolution is that the actors in the network may evaluate the network structure and try to obtain a 'pleasant' (more neutrally stated, 'positively evaluated') configuration of relations. The actors base their choices in the network evolution on the present state of the network, without using a memory of earlier states. However, they are assumed to have full knowledge of the present network. ... It is immaterial whether this 'network optimization' is the actors' intentional behavior; the only assumption is that the network can be modeled *as if* each actor strives after such a positively evaluated configuration. (Snijders, 2001a, p. 4)

Although the notion of intentionality (or perhaps the lack of it) may raise a red flag here, the equations of the model are flexible enough that the "intentionality" is really only a weighted tendency for the *algorithm* to seek certain network configurations -both intentional and non-intentional properties of actors could be represented in this fashion.

SIENA's method for estimating network parameters is simultaneously elegant and ridiculously brute-force. Because it is generally not possible to derive analytically the various network effects from observed data, a Monte Carlo search of possible model parameters is run. For each parameter setting, a stochastic Markov process is used to generate the network specified by the model, and this network is compared to the observed network. The process is repeated thousands of times until (hopefully) there is convergence on a set of parameters which are capable of generating networks which change over time in ways which are measurably similar to the observed networks. By generating a large number of networks with the same parameter settings, a rough idea of standard deviations and errors can be obtained as well.

There are several things which are problematic about this method. Because it is essentially a stochastic process, there is a limited degree of repeatability. And, just like in any other comparison of models to real data, just because the model fits the data doesn't mean that it is the best possible or most accurate description of the data. I particularly appreciated the comment in Skog's paper:

> At the risk of stating the obvious, I should stress at the outset that the nature of this dynamic cannot be logically deduced from the data. The deductions go in the opposite direction. From presumed mechanisms once can deduce certain structural features. When present, these empirical facts may be said to support the proposed mechanisms, but since it will always (or nearly always) be possible to find other mechanisms with similar consequences, support is not the same as proof. (Skog, 1986, p. 4)

Also, the process of eliminating unnecessary parameters from the model is a fairly subjective one, and may introduce biases towards expected effects. One advantage of Snijders's approach is that, unlike the QAP permutation approach, it does not simply use random networks of equivalent density for significance estimation; it generates networks of the same hypothetical model class and makes comparisons with multiple statistics. Another advantage of SIENA is that not only will it estimate the relative effects of various network generative functions, it will also estimate the impact of traits held by the actors (individual covariates), or relations between the actors (dyadic covariates), if the data files are included along with the network matrices. This makes it possible to investigate the role of other structural networks (house membership, etc.) in mediating the formation of the observed networks, or the role of attributes like sex.

To investigate the potential network effects present in the name recognition network (Net 0), I fed in the 22 x 22 networks for each of the three waves, starting the analysis with several parameters and eliminating those which were least significant, as suggested in Snijders' documentation (Snijders, 2001b). Throughout the analysis, the model generally exhibited very good convergence, such that when the deviations of observed parameters during the run are compared to the goal parameter, the "t"-statistics are very close to 0. Most parameter estimates are based on around 1400 iterations. The rate parameter estimates are based on 500 iterations, and describe the number of changes per actor estimated to have occurred between the observations, including canceling changes. The other parameters indicate the weights for the objective functions of their respective network effects. After the estimates of parameter significance were complete for each Net, I repeated the analysis from scratch, including a house affiliation dyadic covariate matrix (discussed below) The models still showed excellent convergence, and similar significance. Tables 4 through 6 show the estimates and significance of the parameters arrived at for the name recognition network, the "at least weekly" conversation network, and the "at least daily" conversation network. A "t"-test value greater than 2 indicates significance at the 95% confidence level. In some runs, non- significant

effects were included for comparison, although this is likely to reduce the significance of other effects.

| SIENA estimates for Net 0 | Estimated Parameter | Standard Error | "t"-test |
|---|---|---|---|
| Rate parameter period 1 | 5.5197 | 0.5698 | 9.687 |
| Rate parameter period 2 | 3.5731 | 0.4633 | 7.712 |
| **density (out-degree)** | -0.7272 | 0.3081 | -2.361 |
| **reciprocity** | 0.6819 | 0.1913 | 3.565 |
| popularity of alter | 2.4919 | 0.4332 | 5.752 |
| houseAffil (centered) | 0.3269 | 0.2156 | 1.516 |

Table 4 Results of SIENA parameter estimation for 22 x 22 name recognition matrices

| SIENA estimates for Net 1 | Estimated Parameter | Standard Error | "t"-test |
|---|---|---|---|
| Rate parameter period 1 | 3.6631 | 0.5691 | 6.437 |
| Rate parameter period 2 | 1.6297 | 0.3291 | 4.952 |
| density (out-degree) | -0.8045 | 0.4720 | -1.704 |
| **reciprocity** | 1.7217 | 0.3455 | 4.983 |
| **balance** | 3.1383 | 0.9773 | 3.211 |
| popularity of alter | 1.3921 | 0.9083 | 1.533 |
| houseAffil (centered) | 0.4781 | 0.2912 | 1.642 |

Table 5 Results of SIENA parameter estimation for 22 x 22 "at least weekly" conversation matrices

| SIENA estimates for Net 2 | Estimated Parameter | Standard Error | "t"-test |
|---|---|---|---|
| Rate parameter period 1 | 3.076 | 0.6363 | 4.834 |
| Rate parameter period 2 | 1.0578 | 0.3173 | 3.334 |
| **density (out-degree)** | -2.3114 | 0.2772 | -8.338 |
| **reciprocity** | 3.1006 | 0.4736 | 6.547 |
| houseAffil (centered) | 1.0565 | 0.3859 | 2.738 |

Table 6. Results of SIENA parameter estimation for 22 x 22 "at least daily" conversation matrices

Although it is difficult to summarize the trends in the various effects due to the somewhat haphazard nature of the analysis, there appear to be several which are significant. The most consistent result is that the rate parameters of the two time blocks differ; the estimation shows 2 to 3 times more activity between waves 1 and 2 than between waves 2 and 3. There is also a large reciprocity effect at all of the network levels, but both the weight parameter and significance are greatest in the daily conversational interaction network. Reciprocity indicates mutual selection: if **i** chooses **j**, **j** is likely to choose **i**. It makes sense that

the effect would be the strongest in the daily interaction network, because repeated daily conversations generally require mutuality, where name recognition can be one-way if there is a "celebrity effect". In fact, there appears to be a popularity effect which is strong and significant for name recognition, but not for the other two networks. This suggests that there are some individuals in this freshmen sample whose names are recognized regardless of their network location. There is a negative density effect which is strongest and most significant in Net 2, and this is consistent with the results of the outdegree plots for the whole data set. This might indicate some sort of "cap" on daily conversations - individuals with high outdegrees are unlikely to add more connections. There were several other effects that were significant in one or two rounds (balance, transitivity), but as these estimates are only for the 22 x 22 matrices, the samples size is probably too small for them to be reliable. I also attempted to use the individual covariate feature to investigate the possible effects of sex on interactions, but the results were neither significant nor consistent. All of these findings should be checked by repeating the analysis with a larger sample of the data set - this would be possible because SIENA allows some missing values in the matrices - and by using the simulation mode of the software to investigate the distributions in more depth.

In an earlier section of the paper I suggested that a useful way of visualizing the effects of social structure on interaction was as a collection of networks describing the parameters which might promote or discourage interaction to some degree. The idea is that observed interaction is a result of the sum of the various effects. At Bennington, house membership could potentially be a strong predictor of interaction. It has certainly been my experience that members of the same house tend to hang out together. One reason might be that because the housing office attempts to maintain the "personalities" of the houses, the individuals placed in a house are similar in some respects and would be likely to interact anyway. In later semesters people have the option of changing houses to be with their friends. But for the freshmen, it seems that house co-membership could be considered as a kind of structural embeddedness, both social and physical, which may foster increased interaction among

residents. The results from the SIENA analysis seem to indicate that this is the case, at least for the daily conversation network. Because the respondents indicated their residence in the demographic portion of the survey, it was possible to transform the information into a respondent x respondent affiliation matrix with ties between the actors that share a house. This matrix was then given to SIENA as a dyadic covariate file to be included as a parameter for estimation.

| | Wave 1 | | Wave 2 | | Wave 3 | |
|---|---|---|---|---|---|---|
| Simple Matching | corr. value | p-value | corr. value | p-value | corr. value | p-value |
| Net 0 | 0.753 | 0.142 | 0.643 | 0.062 | 0.576 | 0.062 |
| Net 1 | 0.803 | 0.113 | 0.779 | 0.01 | 0.751 | 0.016 |
| Net 2 | 0.807 | 0.104 | 0.842 | 0.004 | 0.827 | 0.006 |

Table 7 Estimates of correlation between the house affiliation matrix and the other 22 x 22 matrices

As a check on the slightly "black box" SIENA methodology, I also used UCINET's QAP correlation procedure to directly estimate the ability of the house affiliation network to predict tie formation. Table 7 shows that there are fairly strong and significant correlations between the house affiliation network and the daily conversation network for wave 2 and wave 3. This seems to agree with the SIENA results, suggesting that house membership may not be important for name recognition, but it does affect who people interact with on a daily basis later on in the term. Again, I would have much more confidence in these results if the 22 respondent sample was considerably larger and less skewed in house membership.

Figures 29 - 31 show the 22 individuals who were present in all three survey waves plotted by their residence against a map of the physical layout of the college. In these networks, the ties from Net 0, Net 1 and Net 2 are aggregated on the same graph and indicated by color coding. This layout makes it quite clear that the sample of 22 is not very representative of the College, at least as far as housing is concerned. It is not possible to determine whether the large number of ties relating the two houses with the most respondents is due to a large degree of social interaction between the houses or, more likely, due to the high connectedness of subsets property of random graphs. In these images it is also difficult to see

what is happening with the in-house ties.

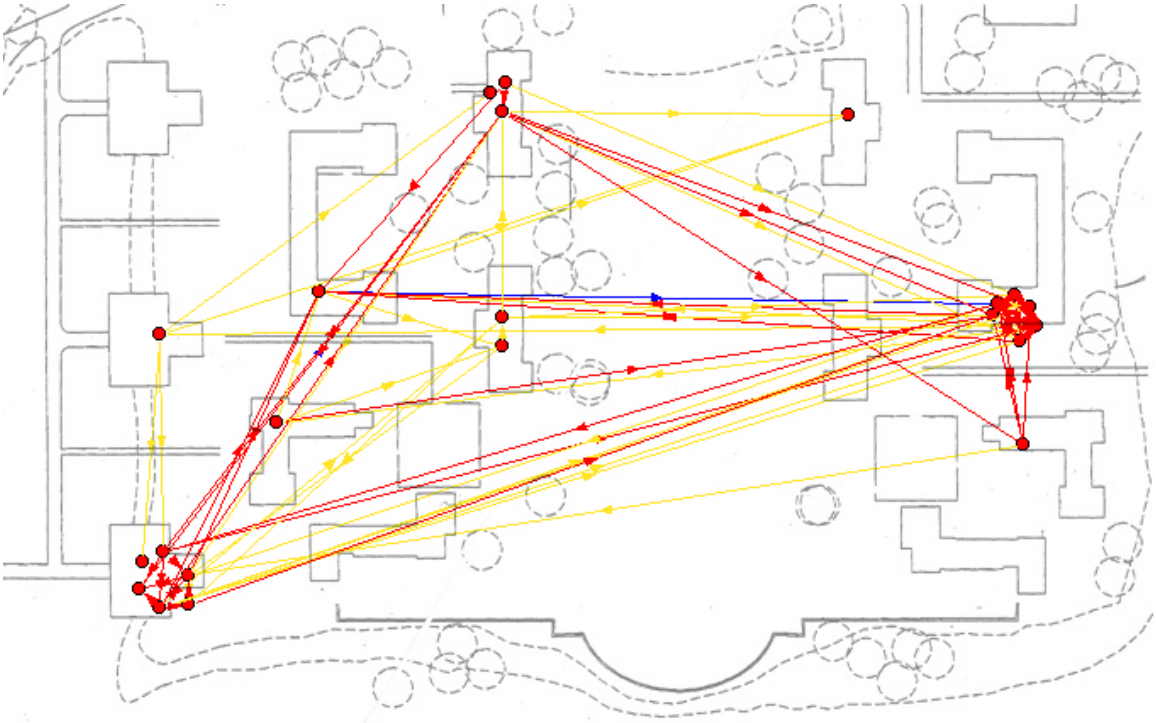


Fig. 29 Spatial representation of the Wave 1 connections in the 22 network superimposed on a map of the Bennington campus. Nodes are position according to the geographical coordinates of their residence.

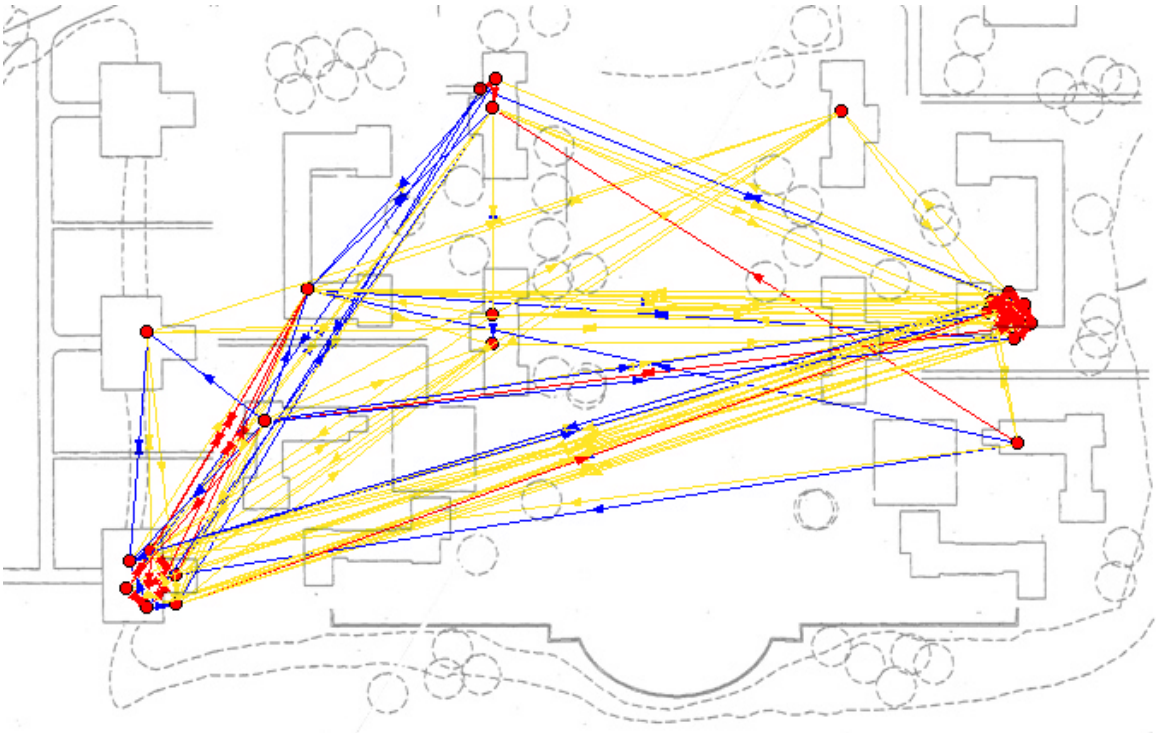


Fig. 30 Spatial representation of the Wave 2 connections in the 22 network superimposed on a map of the Bennington campus. Nodes are position according to the geographical coordinates of their residence.

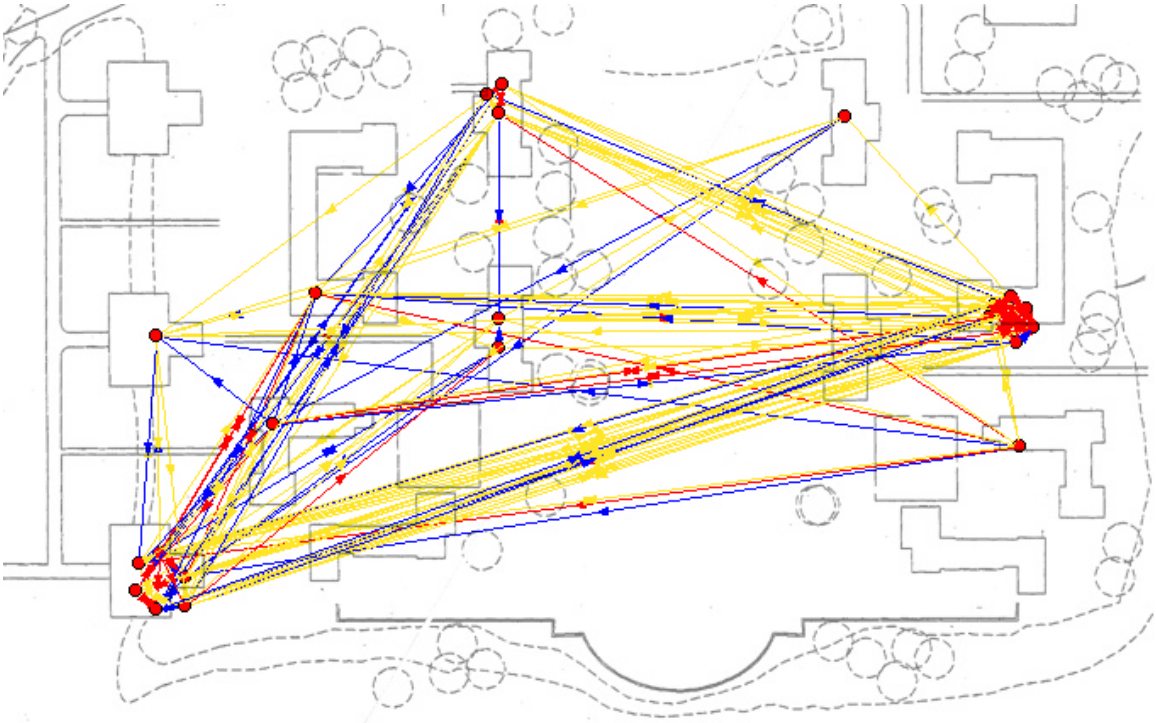


Fig. 31 Spatial representation of the Wave 3 connections in the 22 network superimposed on a map of the Bennington campus. Nodes are position according to the geographical coordinates of their residence.

To correct for this, it is possible to display the networks using a spatial layout which is based solely on the pattern of ties rather then the physical location of the respondents. A commonly used method is Multidimensional Scaling - which attempts to optimize the locations of the nodes so that the Cartesian distances between them corresponded well to a parameter like graph theoretic distance. However, MDS requires symmetric data as input, which would mean discarding a great deal of detail from an already sparse data set.

Another common technique is to use one of a number of "spring embedding" algorithms to position the nodes. Spring embedding techniques generally treat the edges between the nodes as springs of a given weight, and iteratively adjust the locations of the points until a "minimum energy" configuration is found. The problem is that many of the routines are stochastic, poorly understood, and there may be multiple local minima at which the layout can get stuck, meaning that the results can be highly dependent on the given starting positions for the nodes. The layouts for Figures 32-34 were constructed using the Kameda-Kawai algorithm in the recently

developed free network analysis software PAJEK (Batagelj & Mrvar 2001). All of the figures were constructed with the same initial configuration of the 22 nodes arranged around a circle in sequential order. This means that although they may not be the clearest or absolute "lowest energy" representation, they are repeatable and comparable to each other.

These graphs convey qualitatively many of the features detected in the SIENA analysis: (1) the graphs for the name recognition network become increasingly connected and dense with time; (2) the conversation networks seem to show some degree of segmentation, especially in the 2nd wave of Net 2; and (3) the individuals in the segments correspond quite strongly to the house groups in the spatial layout. The subset nature of the networks is quite clear as well; the Net 2 networks appear to function as a core or "backbone" for the Net 1 networks. It is also interesting that the differentiation between the classes of networks seems to increase with time. Net 0, Net 1 and Net 2 in wave 1 are qualitatively quite similar, as opposed to the strong contrast between Net 0 and Net 2 in wave 3.

The patterns of connections evident in these graphs can be somewhat misleading, as the only connections shown are those between the individuals in the 22 underclassmen sub-sample. In other words, nodes which appear isolated in these graphs may be quite highly connected, but their ties are to individuals who are outside of the sample or didn't respond to the study. Figures 35-37 show bi-partite graphs of the "at least daily" out-connections for each of the 22 respondents in the sub-sample. Each of the white nodes (open circles) corresponds to one of the 250 target names in the survey, and the shaded nodes denote the respondents. For clarity, all of the targets with no incoming ties were removed. The graph is slightly confusing because the 22 respondents are displayed in two locations, both as a respondent and as a target, and the connections between the respondents are not directly shown. The advantage is that it better illustrates the presence of many two-step ties and connections to individuals not included in the sample. The graphs also demonstrate how complicated these representations can become. I have not included the graphs for name recognition or for the complete set of respondents because they become so dense that they are almost illegible unless displayed in an animated 3D format.

Fig. 32

Network representation of changes in the ties of name recognition (Net 0) over time

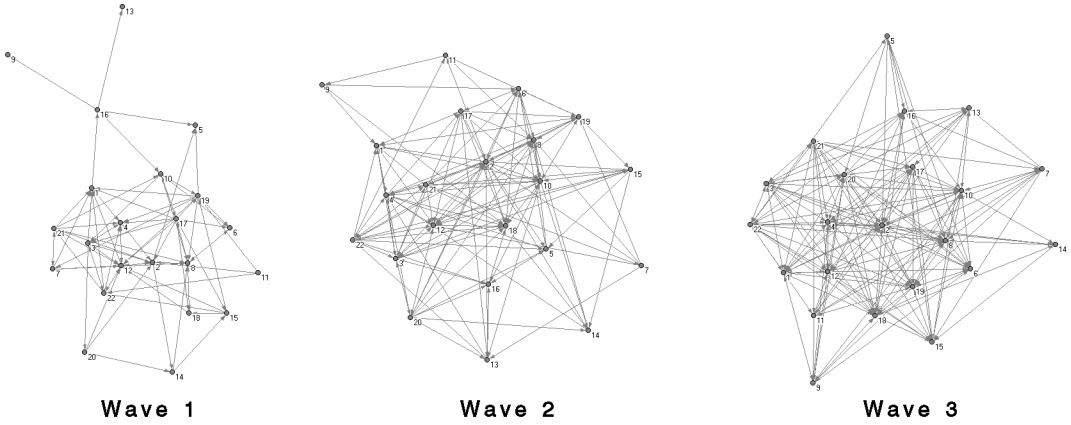



Fig. 33

Network representation of changes in the ties of "at least weekly" conversation (Net 1) over time

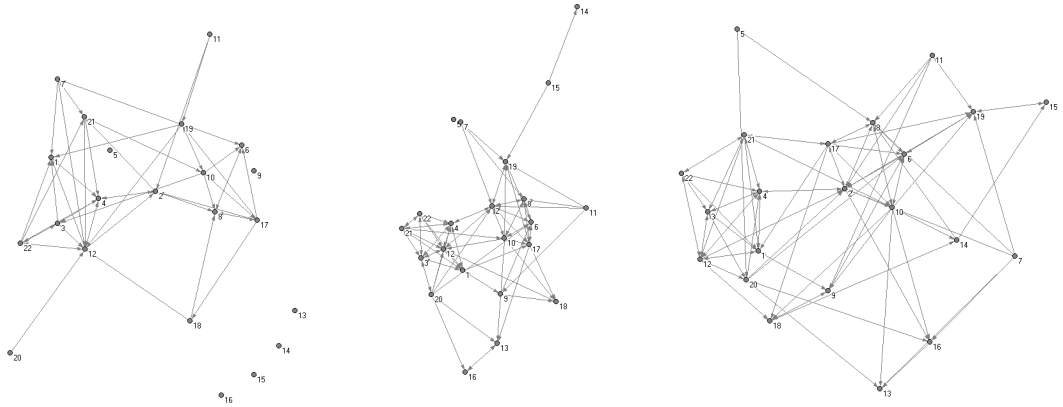
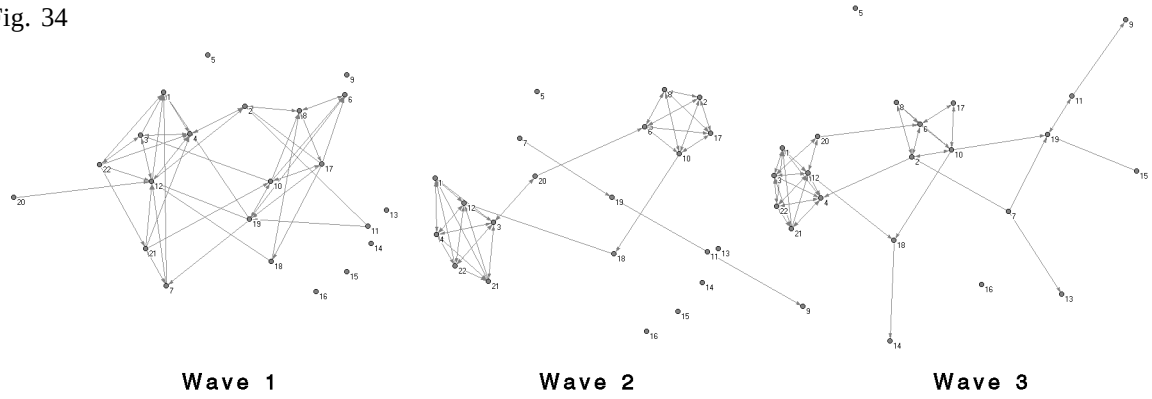



Fig. 34

Network representation of changes in the ties of "at least daily" conversation (Net 2) over time



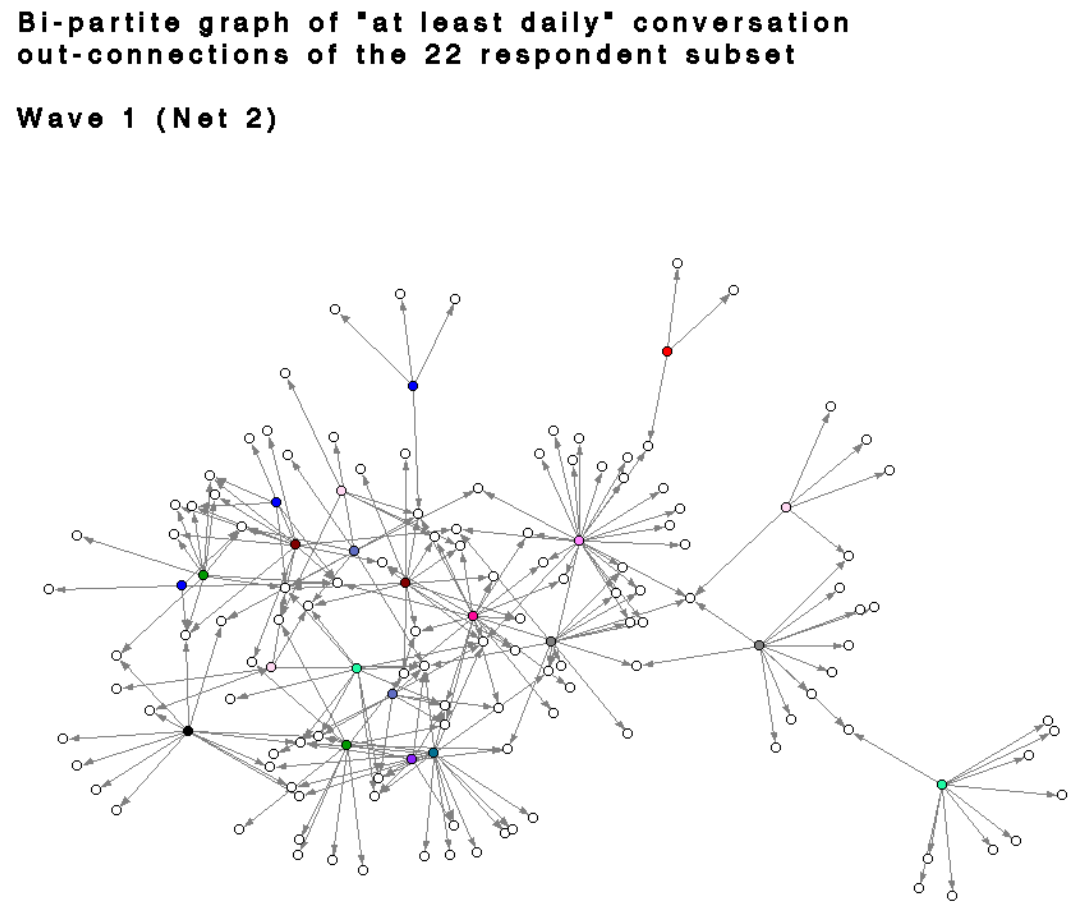



Fig. 35 Spring embbedd layout of the Bi-partite graph connecting the 22 respondent subset to the 250 target names.

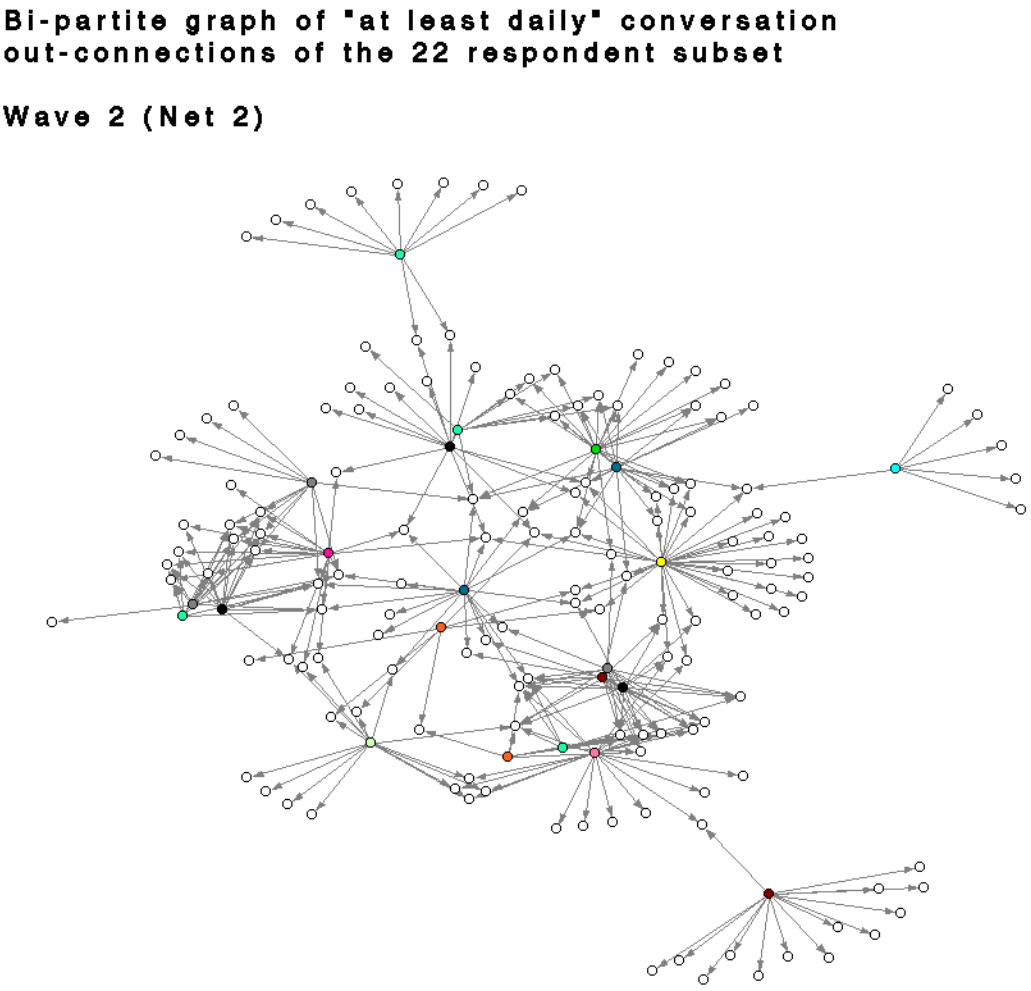



Fig. 36 Spring embbedd layout of the Bi-partite graph connecting the 22 respondent subset to the 250 target names.

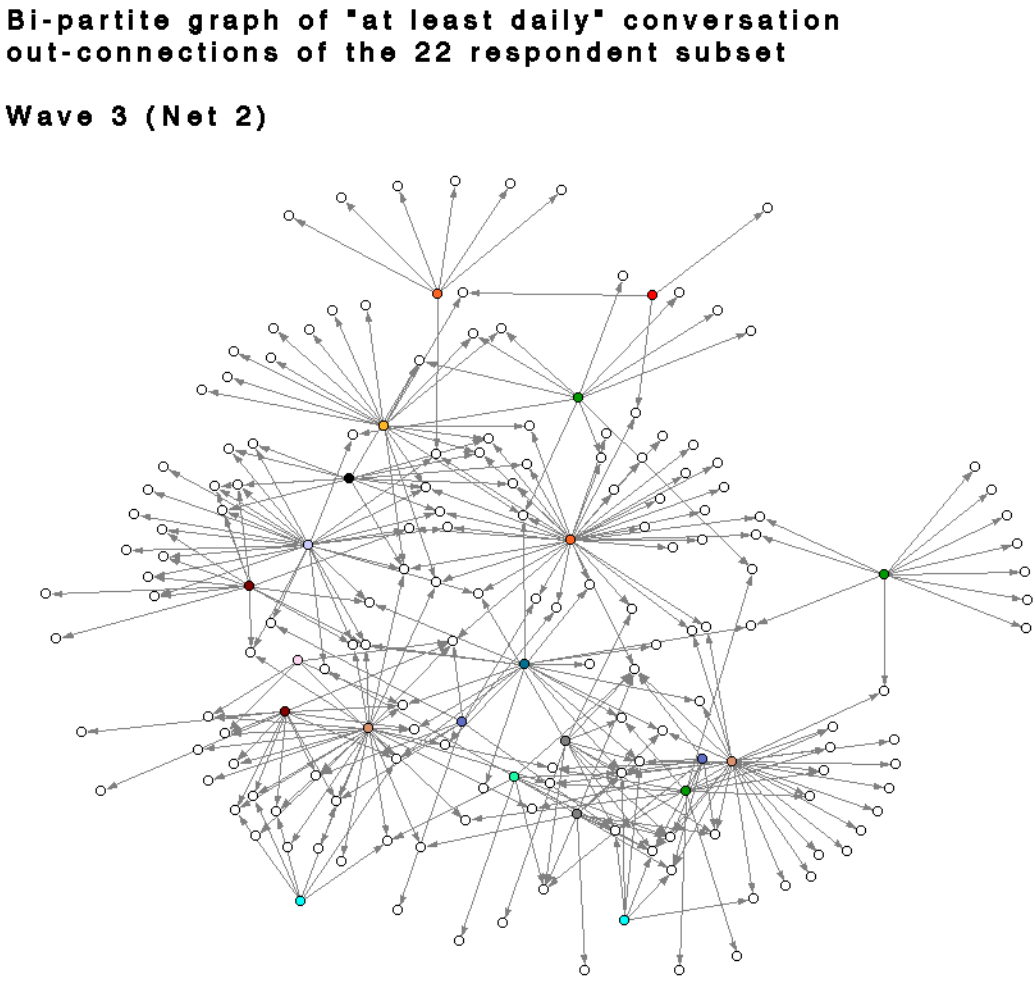



Fig. 37 Spring embbedd layout of the Bi-partite graph connecting the 22 respondent subset to the 250 target names.

**Implications of the study results**

A crucial question is how the data I have collected can be used to support or contradict the assumptions I've been making about models of social group formation or information and cultural transmission. In a sense, by testing the relative importance of various effects on the formation and dynamics of social networks, I'm already assuming one of the things I'd like to demonstrate: that information flow is closely related to communication networks. What I have not done is directly examine the dynamics of information and culture. However, I believe that the data I have presented provide fairly convincing evidence both for the existence of growth

and change in the social environment studied, and for the feasibility of using this kind of survey instrument for obtaining meaningful data. I have complete network data on fewer than 30 individuals, so statistical resolution is less than overwhelming, yet I believe it is still possible to reject two crucial null hypotheses. The first null hypothesis is that the methodology is inappropriate and the collected data are spurious, exhibiting no consistent relationship to the actual patterns of social relations among the respondents. The highly significant rejection of the control group (the dummies) by the respondents, the relative consistency of the responses, the presence of detectable structure in the data, the agreement with qualitative impressions, and anecdotal accounts from the participants, all argue convincingly that the participants took the study seriously, answered to the best of their ability, and that the data in some way reflect real world relations - as much as such data can. They second null hypothesis, that there are no observable trends in the data which could not be best accounted for by random error, can also be rejected due to the strongly significant increase in name recognition outdegree over time, and the changing correlations with respect to static matrices.

I believe that the "success" of techniques based on description of network dynamic effects and structural relations in predicting (albeit retrospectively) the observed data provide grounds on which to accept tentatively the feasibility of models which conceptualize the gross dynamics of human relationships withen a social network framework. By that I mean that even if useable predictive models are still out of reach, at least the idea of modeling individual relations as dependent on network structures and variables with a scope larger than the dyad seems to be on the right track. The results also emphasize the importance of considering social relations as inherently time based. There are considerable amounts of change at all levels of the survey data, more than could easily be accounted for by simple survey error. The high degree of changing relations and rates suggest that in many cases, representing a network as a static "snapshot" would mean sacrificing some of the most crucial information.

Can any specific conclusions be made about Bennington from the data? Although the

results of various analyses suggest strong effects within the sample, mapping results from that data onto conclusions about the real world is somewhat tricky. My original intention was to come up with estimates for "cliqueishness" and average "social distance" for the campus, or at least the freshmen social network. It is, however, the nature of networks that they do not segment well into useable subsamples. That is, estimates of some properties do not scale well from a sample to a population. For example, if the sample of 22 individuals was truly random, the likelihood of getting multiple individuals who are members of the same close social group would be quite small. (Klovdahl, 1989) So simply scaling up the number of cliques observed in the sample to the population size would probably result in a gross underestimate of connectivity. More advanced extrapolation techniques could be used, but they would necessarily entail some strong assumptions about the unobserved properties of the network.

The same problem exists for geodesic distances. There is a good chance that any given distance between two individuals would in fact be considerably shortened by the inclusion of the un-recorded connections to a non-respondent. Some of these data could potentially be extracted from the much larger collection of bi-partite data, but considerable work would need to be devoted to coming up with an appropriate methodology. I was quite surprised to discover during the analysis that there is no real procedure for estimating the correlations between non-square matrices. As I mentioned earlier, this necessitated the exclusion of a great many data on connections to non-respondents and upperclassmen for many of the analyses. So the few tentative conclusions I have made are really more about general properties of network formation, as observed at Bennington, rather than about properties of Bennington's networks.

However, the results do have some interesting implications. It seems that by the end of their first term at Bennington, the freshmen recognize the names of roughly a third of the freshmen and a quarter of the upperclassmen. They claim to converse at least daily with less than 5% of the campus. There appear to be a few people whose names are known by nearly everyone, but the vast majority are recognized by a much small fraction. Respondents learned names at a relatively high rate, but this rate appears to decrease with time. There is some

evidence of less then perfect mixing between the freshmen and the upperclasses. Who people talk to on a daily basis appears to be somewhat determined by what house they live in, and some individuals seem to be consistently tardy in filling out sociological surveys!

Even though I have devoted a great deal of space in earlier sections to a discussion of information and culture transmission, this study was not designed to examine transmission directly. Mostly this was due to the difficulty in conceving of an appropriate methodology, but also because, as I mentioned before, if the assumption is made that transmission requires communicative contact, an examination of contact may provide an upper bound for transmission. My original intent was to conduct an additional study of actual transmission, for which the social network data would provide a necessary baseline for comparison. However, it is important to realize that there is a fair amount of culture or information transmission implicit in the network data I have collected. Knowledge of the names of the members of the Bennington college community can be viewed as a property of the students' local subculture. But, like many cultural traits, name recognition is neither simple nor arbitrary, because knowing people's names has direct utilitarian function. The data in this study show that people recognize the names of far more individuals than they actually claim to interact with on a weekly basis. Are these extra names infrequently encountered acquaintances, or names that have become familiar "second hand" through conversational interactions with others? Are names learned directly from an introduction, perhaps catalyzed by an existing relationship, or by conversational transmission?

A way to clarify the conceptual distinction is to consider the Bennington name recognition ability of the parents of a Bennington student. If their child keeps in touch at all (perhaps an unlikely assumption!), the parents might become "enculturated" with the names of the student's close friends and instructors, despite the fact that they have not been introduced in person. I would argue that this is an example, and a measurable one, of information and cultural transmission. The name recognition data in this study can be conceived of as a combination of cultural knowledge and network information. Unfortunately, this complicates

the issue and does not provide a clear means of separating out the variables. However, a separation may not be necessary, if the questionable choice is made to assume what we are trying to establish: Independent of whether the names are learned through direct interaction and introduction or second-hand through gossip, in most cases the knowledge is still mediated by conversational contact. That is, it might be expected that individuals would be more likely to learn the names of people who are at short acquaintance-chain distances from them in the Bennington network than the names of those who are further away. This hypothesis could be tested directly by examining correlations between the appearance of new names and the distances on the conversational networks. Unfortunately, this would again require a much more complete data set or the ability to estimate correlations between non square matrices. And a positive result still wouldn't establish whether cultural or informational items which are not as closely tied to interaction as name recognition would still be transmitted along the lines of social ties.

Another potentially strong predictor of network ties which I have yet to examine is academic course enrollment. Bennington college is characterized by relatively small class sizes and most courses provide frequent opportunities for discussion, interaction, and the establishment of acquaintanceships or friendships. Most of the respondents completed the course-listing portion in the demographic section of the survey. These data can eventually be

recoded and analyzed in the same manner as the house affiliations.[21] When discussing the house affiliations I mentioned that individuals may have been placed in the same house on the basis of their presumed compatibility, and this may somewhat obscure the structural effects of house membership. There is a related problem with analyzing the structural effects of course enrollment.

Because people usually choose their courses on the basis of interest in the subject, the courses may be encouraging interactions between individuals with similar interests who would have sought each other out anyway. But this again requires the assumption I have been suggesting throughout: that people may preferentially interact with others who are culturally similar to them. If it were possible to establish some sort of "cultural similarity score", it would be feasible to test for these effects in the data. Although the question of what traits such an index should be based on is closely tied to the unanswered questions of this thesis, an extremely crude analysis could be made on the basis of country or region of origin, or native dialect. Bennington has a substantial international student population, and it is my experience that individuals from the same country tend to associate preferentially with each other. This assumption could be tested in further analyses.

## X. Conclusion

This paper began with an brief description of my experience in the complex group dynamics of a political protest in Washington D.C. I chose to open with that topic because the bulk of the discussion I have presented is fairly academic and abstract. I wanted to provide a real world example of why this sort of quasi-philosophical hair splitting is relevant to

[21] In addition, the data could provide a fascenating tie-in to Shazia Rahim's (2001) research on Bennington's curriculum structure and faculty interaction networks.

everyday life and real problems. I believe that a better understanding of communication and cultural processes could have important real world applications, especially as this is a period in which the modes of media, and the associated power implications, are somewhat in transition. I also feel that it is important to keep the pragmatic elements of a realistic setting salient as a reference point for the more academic discussion: how does one decide what course of action to take in a confused and possibly dangerous setting? My hunch is that we look around to see what others are doing, ask people who may be in the same situation, try to recollect what we have seen or heard of others doing in the past, or try our luck with constructing a response based on our knowledge of the world and how it works. This set of basic "common sense" knowledge is one of the crucial aspects of culture.

Arguments have been made that the ability to construct and pass on systems of interpretation, meaning and behavior is uniquely human. But there at least is some evidence that species other than humans have limited non-genetic means of transmitting behavior. The very limited selection of research presented here on communicative processes and culture in animals suggested that a better understanding of what is meant by "Culture" in humans in necessary before any conclusions can be drawn about its presence or absence in animals. Because many kinds of communicative behaviors have been observed in animals, it seems likely that the presence or absence of language may be a matter of degree. I do not necessarily mean to say that there are other species that use abstract symbol systems to communicate, just that it is difficult to see where a sharp line could be drawn between intentional and "mindless" use of symbolic signaling. Humans certainly appear to have the most extensive and well developed language/symbolic/culture system. Why this might be and how it may have occurred over evolutionary time is an open question. Are cultural processes adaptive, that is, do they confer fitness benefits on the individuals of species that employ them, or are they a side benefit from some other process that was selected for at some point in our evolutionary past?

It is easy to come up with reasonable situations where the presence of cultural transmission could affect genetic fitness, so it must be taken into consideration when testing

evolutionary hypotheses. (Consider the possible genetic effects of the emergence of assortitive mating which is based on a cultural parameter.) Because the mechanics of cultural transmission may be quite divergent from genetic transmission, it is difficult to predict how they might interact, or which effects would dominate in a given evolutionary situation. It may be possible for traits to be adaptive in a cultural regime and not in a biological one. Certainly there is the potential for the emergence of structures which are more complex than might be predicted by biological evolution acting alone. The concept of a bio-culturally stable strategy may prove to be a useful tool for dealing with the intimidating proliferation of possibilities. I am also attracted to the idea of describing the evolution of culture-capable organisms as a co-evolution: traits are being selected for in multiple regimes, the species is balanced between them, but minor change in one direction may drive further evolution in another.

The biologically evolved and adapted activities of humans as communicators and sense-makers could potentially create adaptive landscape in which some patterns or messages, cultural or semantic, can increase in frequency at the expense of others, and possibly at the expense of traditional biological fitness. In other words, some of the formal properties of communicative processes in humans seem to suggest the possibility for differential propagation of cultural traits or information "messages." If this is the case, the concept of diffusion or percolation along network ties may be a useful way of thinking about culture transmission. But what are the "messages," "cultural items" or "information units" which I have so consistently avoided defining?

Two general frameworks for thinking about information have been brought forward in the course of this paper: Shannon's concept of information as reduction of uncertainty, and a rough idea about information transfer increasing similarity of perceptual schemas or interpretive frameworks through some process of modification or induction of corresponding semantic elements in the interactants' meaning spaces. Obviously a great deal more work is needed if these suggestions are to be refined from mumbo-jumbo to a usable definition. The factor analysis techniques of Osgood and his more recent colleagues (Pocklington, et al., 1997,

Romney, et. al., 2000) seem like a promising avenue to pursue.

The research for this project has greatly increased my appreciation of the tensions and paradoxes inherent in the process of creating meaning and knowledge for oneself and trying to communicate it to others. Statements which conform entirely to expectations might as well be left unsaid, as they contain no information, yet uses or messages which are too bizarre and diverge too far from the norm will probably not be recognizable enough to be decoded. I now see meaning as a consensus process involving the individuals in communication; the use and connotations of each reference must be negotiated by the participants into something which is reasonably congruent between them, yet still consistent with their own interpretive frameworks. To me this leads to an increased sense of the relativity inherent in systems of symbols, language, and meaning.

I have found Campbell's use of the concept of bias, and its development by Boyd and Richerson, to be quite widely applicable. Rather than thinking of effects as rigidly derministic functions (never a good idea for anything involving real people!), they can be thought of as an increased tendency to err in a particular direction or oversample in a certain way, with the effects perhaps only detectable as the deviation of a population mean from its expected value. There are, for example, some patterns of "human error" in communication which can be expected whenever humans open their mouths - even if individuals are working to tell the "truth" to the best of their knowledge, they are still more likely to omit what they do not understand, etc. Yet, remarkably, we manage to get along just fine most of the time, using contextual cues, previous knowledge, and multiple channels of information to assemble an appropriate meaning from even the sparsest of signals with surprisingly little error.

It seems likely that part of the reason for the relatively low rates of errors or specific misunderstandings in ordinary conversational communication is that we utilize a tremendously wide bandwidth of contextual cues to fill in for the details we miss. Communication and information transmission can involve material culture, proxemics, direct action, and omission, as well as the more explicit symbolic content of speech or text. It is important to consider the

patterns of contact with material culture and its overt and implicit informational content when considering models of knowledge collection. I believe that a social networks perspective can provide an important framework for dealing with social structure, interaction, and environmental effects simultaneously. Some phenomena, like the small world problem, which initially seem counter-intuitive suddenly make sense when considered from this perspective. In a footnote to their paper, *Robust Action and the Rise of the Medici*, Padgett and Ansell (1993) present what is to me a compelling argument for sociological relations from a network perspective:

> Our general position on the interrelation of social attributes and social networks can now be clarified. Obviously, (contra some occasionally overstated polemics by social network aficionados), we do not believe that social attributes are irrelevant: the particular way in which the Medici recombined social attributes through networks is the heart of the story here. What we object to is the arranging of attributes discretely in groups or spatially as grids - a procedure which presumes that attributes are behaviorally meaningful in a network vacuum. Of course actors in the system, as well as researchers, do exactly these clustering procedures mentally when they analyses their own social structure; this is what "boundedly rational" cognitive classifications are all about. But there is a widely underappricated gap between these macro cognitive (or "cultural") operations and micro behavioral local action taken by concrete individuals in very particular, heterogeneous, and often cross-pressured circumstances. Simplifying social reality into homogenous subsets "with common interests" rips individuals out of their (often contradictory) multiple network contexts and obscures the very heterogeneity and complexity of which organizations like the Medici party are constructed! (Padgett and Ansell 1993, p 1285)

Not that network data always simplify the situation. The problem with working with complex data sets is that the analysis becomes more complicated as well. And, as network analysis is still sort of an infant science (although the concepts have been around for at least 50 years), there are few agreed upon measures and indices for making meaningful comparisons across studies or networks. In many cases the analysis takes a very qualitative mode, using formal criteria to lay out a visualization, and then relying on inspection and intuition for judgments about meaning and further analysis. But I find the models and tools which are being developed from a networks perspective to be both exiting and promising. The notion that contact networks imply transmission networks and so might provide a window into cultural processes is tantalizing, and it is at least not disproved by the data I collected and analyzed.

In this paper I have generally used "communication" to mean an attempt to convey information or the transfer of information between two interacting individuals. But my usage has often been quite sloppy. Part of this is due to the argument I've been trying to make: that there may not be any clear-cut distinction between interaction, information exchange, and communication – they are all part of a graduated process and are to some degree implicit in each other. I've also tried to suggest that communication and culture ought not to be considered separately either; they both involve flows of information, just on different time scales. Although I certainly have not presented a framework comprehensive enough to deal simultaneously with the scales of cultural evolution and gossip, I believe that I have pointed out some similarities which suggest that such a synthesis might eventually be possible.

I think one of the key images which fascinates me, and which I hope to have conveyed effectively, is the idea that even if humans were viewed as nothing more than a collection of arbitrary sense-makers - sucking up information from their social and physical environment and re-emitting it in some fashion - the simple fact of their immense and unpredictable connectivity could lead to the emergence of complex and interesting structures. The individuals in a society could be viewed as enzyme-like "black boxes", spinning out endless variation and catalyzing the syntheses of socially transmitted cultural information, extracting from it patterns and regularities while simultaneously permuting it into innovative, surprising, and often beautiful forms.

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