Communication Technologies and Their Effect on Cultural Homogeneity, Consensus, and the Diffusion of New Ideas

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Abstract

A view of communication technologies as creating artificial agents and affecting the information processing capabilities of agents is forwarded. The constructal theory is adapted to account for agents varying in their information processing capabilities, and hence to account for technology. Given this theoretical modification, the constructal model is used to examine the impact of different communication technologies and socio-cultural landscapes on the rate at which information diffuses and the time it takes for the society to reach cultural homogeneity and consensus. The findings suggest that as the available communication technologies change the role of the socio-cultural landscape in effecting social change varies. Paradoxically, this research suggests that mass-communication technologies that enable greater competition among messages and greater message complexity will enable faster information diffusion, than will those technologies that inhibit competition and message complexity.

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A group of friends leave the theater and begin discussing the play they have just seen, *West Side Story*. "What a poignant portrayal of racial tension in the inner city" says one. "Well", says another, "I think it was a better rendition of Shakespeare's Romeo and Juliet than the original." On and on the comments go. Interpretation aside, it appears that each individual learned something different from the play. Contrast this "actuality," with the common assumption made by the government when they broadcast the emergency alert signal that through telecommunication channels such as radio and television the majority of the society will be reached with the same message — "here's what to do in an emergency." One expects different individuals to learn different information when ideas are passed by word-of-mouth. Rumors, for example, are routinely distorted. However, most people expect less distortion when the ideas are presented by mass-media (debates like that between the friends who saw *West Side Story* notwithstanding).

As communication technologies emerge, different patterns of social behavior are expected to emerge. Newspapers, for example, were expected to shape the beliefs of the masses (Lippman, 1922) and therefore could possibly create a homogeneous culture; but, today's resultant culture is hardly homogeneous. The phone was expected to facilitate within house communication and so minimize interaction with servants; but, it is instead used to keep families in contact (del Sola Poole 1977). Indeed, such technologies may alter some of the fundamental ways in which education and the ties between individuals affect social behaviors such as cultural-homogeneity, consensus, and diffusion. Clearly there is an expectation that mass-communication will lead to more rapid information exchanges and to more individuals simultaneously acquiring the same information (Williams 1961). Therefore, mass-communication technologies should increase the rate at which information is diffused, and homogeneity and consensus are achieved. However, communication technologies are not the sole determinants of social behavior, even that behavior that emerges from interaction. Rather, as is frequently noted, interaction and social behavior are affected by a host of other factors (see for example, Axelrod 1984; Blau 1967, 1977; Collins 1986; Homans, 1950; Turner, 1988). Many of these factors are structural; e.g., the size of the population. Still other factors are cultural; e.g., the complexity of the culture. These factors also affect the

rate of social change. At issue, is whether communication technologies and the socio-cultural landscape interact with each other in effecting social change.

This paper is a theoretical examination of this issue. The impact of various aspects of communication technologies and socio-cultural landscapes on cultural homogeneity, consensus, and diffusion are examined using simulation. This examination takes place using a modification of the constructural model (Carley 1990,1991a). Constructuralism is a dynamic processual theory of social change that provides an integrated and dynamic view of cognition, interaction, and the socio-cultural environment in which the environment through interaction affects cognition which motivates interaction which alters the environment. Previous studies have shown that constructuralism: predicts change in interaction over time better than either balance theory or exchange theory (Carley 1990); is consistent with a wide range of results on social interaction (Carley 1991a); and is consistent with research on inter-generational tension (Carley 1991b). The implications of the constructural perspective for societies affected by print and authoring has been examined in detail by Kaufer and Carley (1993). In this paper, I expand the constructural framework to include at least the rudiments for dealing with technology. Then, using the expanded theory (and the associated expanded model) I explore the implications of this theory regarding the ability of communication technologies to effect social and cultural change.

This paper brings together two largely disconnected lines of research — that on social structural influences on information diffusion and that on communication technologies. In this paper, the concern is with that aspect of socio-cultural change (changes in homogeneity and consensus) that results from the diffusion process. Thirty years ago, Katz, Levin and Hamilton (1963, p. 238) argued that the "underlying assumption was always that informal communication among adopters was the key to diffusion." A great deal of research has added specificity to this claim and has found that ties between individuals are important to information flow. Yet, while many researchers acknowledge the importance of social structure to the diffusion process (Katz 1961; Rapoport 1953), there are relatively few studies of how the social structure affects information diffusion (Rogers 1983, p. 25). Notable exceptions, however, have shown that differential levels of within and between group ties, the strength of ties among individuals, and the level of integration impact information diffusion (for example see, Becker 1970; Burt 1973,1980; Coleman, Katz, and Menzel 1966; Granovetter 1973, 1974; Lin and Burt, 1975). While this literature demonstrates the role of social structure (and to a lesser extent culture) in effecting social change through information diffusion it ignores the role of communication technology. The

dominant underlying model of communication that pervades this work is one-to-one face-to-face communication.

In contrast, the literature on communication technologies largely ignores the role of the extant socio-cultural landscape. Instead, much of the literature focuses on technological features and usage (Ennos 1990; Rice and Case 1983; Sproull and Kiesler 1986), its psychological and social-psychological consequences (Eisenstein 1979; Freeman 1984; Goody 1968; Kiesler, Siegel, and McGuire 1984; Rice 1984), or historical accounts (Innis 1956; del Sola Poole 1977; Reynolds and Wilson 1978). Admittedly, a common question asked is whether communication technologies will replace or enhance existing networks or social structures (Thorngren 1977). Further, predictions and evidence regarding changes to social structure abound; such as, print made possible the professions by enabling regular and rapid contact (Bledstein, 1976), and electronic communication increases connectedness and decreases isolation (Hiltz and Turoff 1978). The question at issue here has not been asked: "is there an interaction between structure and technology; i.e., does the type of socio-cultural landscape that facilitates rapid diffusion (and so homogeneity and consensus building) change as the type of communication technology available changes?"

AUGMENTING THE THEORY: CONSTRUCTURALISM AND TECHNOLOGY

According to constructuralism both the individual cognitive world and the socio-cultural world are continuously constructed and reconstructed as individuals concurrently go through a cycle of action, adaptation, and motivation. During this process not only does the socio-cultural environment change, but social structure and culture co-evolve in synchrony.

Carley, 1991a, defined the following primary assumptions in describing constructuralism:

- "(1) individuals are continuously engaged in acquiring and communicating information
- (2) what individuals know influences their choices of interaction partners
- (3) an individual's behavior is a function of his or her current knowledge"

In addition to these primary assumptions there were a series of implicit assumptions that upon explication serve to clarify and expand the primary assumptions.¹ Following is an expanded list of assumptions, numbered to clarify their relation to the primary assumptions:

- (1a) individuals, when interacting with other individuals, can communicate information
- (1b) individuals, when interacting with other individuals, can acquire information

- (1c) individuals can learn the newly acquired information thus augmenting their store of knowledge
- (2a) individuals select interaction partners on the basis of relative similarity and availability
- (2b) individuals engage in interaction concurrently (thus an individual's first choice of interaction partner may not be available)
- (3a) individuals have both an information processing capability and knowledge which jointly determine the individual's behavior
- (3b) individuals have the same information processing capabilities
- (3c) individuals differ in knowledge as each individual's knowledge depends on the individual's particular socio-cultural-historical background
- (3d) individuals can be divided into types or classes on the basis of extant knowledge differences

As axiomatized, constructuralism has little to say about the role of communication technologies. Working within the constructural framework, however, we can begin to address the effect of technology. In order to do this the constructural theory needs to be augmented by (1) broadening the notion of individuals to the notion of agents, and (2) adding assumptions relating technology to agent capabilities.

As White (1992, p. 8) notes "Persons ... are neither the first nor the only form in which identities appear." That is, individuals are not the only type of agent. Agents is a generic term referring to both real actors (human or animal) and artificial actors (either active ones such as robots or organizations, or passive actors such as books). According to Carley and Newell (1992) agents can be characterized in terms of their information processing capabilities (that limit what the agent can do) and knowledge (that determines, within these limits, what the agent will do). As axiomatized, constructuralism focuses on how the information processing capabilities of a certain type of agent, individuals, result in social change. To extend constructuralism other classes of agents must be added and assumptions about individuals must be either generalized to general agent behavior or treated as a special case peculiar to a class of agents. Programatically, when we think in terms of agents assumptions the list of foregoing assumptions change. Assumptions 1a through 1c are seen as dependent on the information processing capabilities of the agent and so peculiar to only certain classes of agents. For example, some agents may not be capable of learning. Assumptions 2a, 2b and 3a are common for all agents. And assumptions 3b, 3c and 3d should be altered as follows:

- (3b') all agents within a particular class have the same information processing capabilities
- (3c') agents differ in knowledge as each agent's knowledge depends on the agents particular socio-cultural-historical background and information processing capabilities
- (3d') agents can be divided into types or classes on the basis of extant differences in either or both their information processing capabilities and knowledge

Now consider the impact of technology. Technologies, particularly communication technologies, can be characterized by the way in which they alter existing agents (add/delete capabilities) or create new artificial agents. Thus, to begin to encompass technology, constructualism can be augmented by adding the following assumptions:

- (4) technology can alter the information processing capabilities of existing agents
- (5) technology can, though need not, create artificial agents with unique information processing capabilities
- (6) technology can alter what knowledge is available, and its initial distribution across the population

Let us consider these assumptions. According to assumption 4 technology can enhance (or degrade) an agent's information processing capabilities. Such capabilities include, but are not limited to, how much information an agent can process, and with how many others the agent can communicate simultaneously.² Radio and television, for example, increased a speaker's opportunities to communicate to the masses. Technology can, as suggested by assumption 5, create artificial agents. An example is the robot which has a limited ability to follow instructions. More to the point, technology creates "agents" by extending the human agent. A book³, for example, can be viewed in this light. The author writes a book and so encapsulates, in an essentially unchanging fashion, some of the author's knowledge at that point in time. The book, as agent, can engage in multiple simultaneous interactions (as multiple people read different copies), and has a unique set of interaction processing capabilities, to wit, it cannot select a partner but must be selected, and it can send information but neither receive information nor learn. The book qua agent is very static. It follows from assumptions 4 and 5 that given the peculiarities of a certain technology assumptions 1a through 1c may change. As to the 6th assumption, note that as technologies emerge new concepts, methods, and vocabulary (all components of knowledge) also emerge. There is also a more subtle effect. The agents who use the new technology, such as the first "authors" after the advent of the printing press or the first users of electronic mail, engage in

the exchange of the new knowledge associated with that technology and create new ideas which they disseminate using the new technology. Only those who have access to the new technology have initial access to these new ideas.

Collectively, these assumptions increase the theory's flexibility. Even though these assumptions suggest that technology can change the agents' information processing capabilities (and hence whether they can select interaction partners), they do not suggest that technology alters the agents' basis for selecting interaction partners. Thus, agents which can select partners, still do so on the basis of relative similarity and availability. Technology alters agent availability and knowledge and so influences who is chosen as a partner when, but not how partners are chosen. Agents discriminate between other agents only in terms of relative similarity and availability, thus an artificial mass-communication agent (such as a book) relative to the single human agent has an advantage — it is widely available. However, this artificial agent is also disadvantaged — its knowledge is unchanging and so will, over time, become less relatively similar to other agents who, like humans, are capable of learning.

INCLUDING TECHNOLOGY IN CONSTRUCTURAL MODEL

This paper takes as its starting point the formulation of the basic constructural model presented, supported, and analyzed in detail by Carley (1990,1991a). In this paper only a brief outline of the basic model will be presented along with a more detailed discussion of those portions of the model that are altered by the new assumptions.

According to the basic formulation there is a fundamental interaction-shared knowledge cycle in which the agents engage. During this process the agents continually cycle through the three phases of action, adaptation, and motivation. During the action phase agents can communicate to, and receive information from, their interaction partner. During the adaptation phase agents can learn, augment their knowledge, and as a result cognitively reposition themselves in the socio-cultural environment. During the motivation phase agents select a potential interaction partners.

Now let us consider how agents' information processing capabilities can affect their behavior during each phase of this cycle. During the action phase, agent capabilities determine whether the agent can communicate or receive information, how much information can be communicated or received, and how many interaction partners can be simultaneously accommodated. During the adaptation phase, agent capabilities determine whether the agent learns (or forgets), the procedure for learning, and whether the learning results in any

repositioning. Finally, during the motivation phase, agent capabilities determine whether the agent tries to select an interaction partner, and if so, how many partners are selected.

In order to further specify the changes in the basic model, various technologies and the associated classes of agents will now be considered. The particular technologies of interest are communication technologies. Research has demonstrated that various communication technologies can have profound social, and even psychological, consequences (see for example, Price 1965; Rice 1984; Sproull and Kiesler 1991). Such consequences are dependent on various features of the technology. One salient feature of many such technologies, such as books, television, and radio, is that they enable mass-communication or one-to-many communication. Another salient feature of many communication technologies, such as books or video tapes, is that they enable some of an individual's ideas to remain intact and unchanged over time, and to be communicated without the individual being present thus admitting communication at great geographical and temporal distances (Kaufer and Carley 1993). By examining a set of communication technologies, each with different salient features, classes of agents can be defined. For the sake of discussion each class of agent that will be examined in this paper has been given a name that characterizes the dominant feature.

People. These agents are capable of only one-to-one communication, can select interaction partners, and can learn. These agents can interact with only one other agent during a particular Time Period and can during this interaction both send and receive information.

Books. These agents are capable of one-to-one or one-to-many communication, cannot select interaction partners, and cannot learn. These agents, during a single Time Period, can interact with all of the agents by whom they are chosen as interaction partners and can during this interaction only send information.

Orators. These agents are capable of one-to-one or one-to-many communication, can select interaction partners, and can learn. These agents can interact with one or more other agents during a particular Time Period and can during these interactions both send information to all the listeners but receive information from only one speaker.

Clearly, these agents do not span the space of all possible agents. These agents are stylized such that they separate two communication characteristics of interest — one-to-many interaction and learning. Books, unlike individuals (i.e., people or orators), cannot learn. People, unlike mass-communicators (i.e., books or orators), cannot engage in one-to-many interactions. Further, these agents are interesting from a socio-historical perspective as

they have well defined analogs in the real world and/or are associated with major historical periods.

The class "people", for instance, corresponds to the basic human scenario sans technology. Each agent has a base of knowledge which can be communicated to others and which grows as information is acquired from others (i.e., they learn). Such communication occurs slowly, for example, during face-to-face interactions. A society of such agents corresponds, roughly, to a pre-print, pre-tele-communication world where individuals are prohibited from gathering en-mass to listen to a speaker. Another analog, is the small group engaged in a task requiring only individual exchanges and no group meetings.

In contrast, the class "books" corresponds to the agents made possible by the modern printing press circa 1450 (see Kaufer and Carley 1993). Books are Giddens' (1987, p. 216) cultural object where the culture or information is separated from the source. Books as agents are unalterable in their knowledge but infinitely available. A society composed exclusively of such agents would correspond to a library, the works of knowledge growing covered with dust as they remain unused and unchanging over time. A society composed of people and books, which is what is examined in this paper, is more interesting in that, although the books cannot change, the people can as they read the published books.

Finally, the class "orators" corresponds to a basic mass-communication society. These agents each have a base of knowledge which they can communicate to others and which grows as they acquire information from others, and learn. Such communication can occur slowly or quickly depending on whether the agent is engaged in a two-way exchange of information to a single other or "teaching" to a crowd. A society of such agents corresponds, roughly, to a scholarly convention or a technologically enhanced community where through telecommunication each individual can communicate with a single other, gather en-mass and listen to a speaker, or be the speaker communicating to the gathered crowd. Another analog, is the small group engaged in a task which requires both one-to-one interactions and group meetings.

Despite these technologically induced differences, these three different classes of agents have similarities. Many of these similarities take the form of additional constraints on communication and learning. These constraints are in effect the simplifying assumptions made in the basic structural model. All agents, when they communicate send a single piece of information and all information known by the agent is equally likely to be communicated.

Person-person, person-book, and person-orator communications all take the same amount of time. None of the agents forget and learning (when it occurs) is perfect.

Let us now consider some of the theoretical implications. According to this theory, asymmetries in two agents probabilities to interact with each other can occur simply because (1) agents evaluate their probability to interact with each other agent relative to their relationship to all other agents in the society and (2) two agents may have different relationships to others in the society (i.e., their ego networks differ). In other words, relative evaluation in addition to differential information processing capabilities, given different ego networks, produces asymmetric behavior. Imagine that information is distributed unequally across the society; i.e., there are agents who simply know more than others. Then, for a particular pair of agents, the agent who knows more is less likely to initiate interaction than is the agent who knows less (assuming both agents can initiate interaction). Therefore, over time, since individuals can learn and books cannot, individuals will become less likely to choose the book over another individual as an interaction partner. If an individual makes a discovery (new information) and does not put it in a book, since individuals can learn, over time the individual will become less likely to tell others of the discovery. In contrast, if the discovery appears in a book, since books do not learn, the book will remain constant in "its tendency" to communicate the discovery. The books' message does not become "diluted" over time as it cannot start to communicate other messages.

DESIGN OF STUDY

Using the constructural framework I examine the relative impact of communication technologies and the socio-cultural environment in effecting social change in the rate at which information diffuses and cultural homogeneity and consensus are achieved. In order to do so, two things need to be defined. First, the simulated societies and the classes of agents within them need to be described. Second, measures need to be defined for these rates.

Characterizing Societies

In order to simplify this analysis I will consider societies that can be characterized as single group societies; i.e., there are no barriers to communication in the form of different pre-defined within and between group ties. Individuals, however, will vary in the strength of their ties with other individuals based on differences in what they know. Within these societies factors which can effect change are the size of the population (number of people), the complexity of the culture (number of pieces of information), the initial level of education

(percentage of possible knowledge known by individual), hence the average strength of tie among the individuals in the society, and the available communication technologies. To understand the impact of socio-cultural environment a set of societies varying in these dimensions was simulated. Specifically the societies had either 6, 12, or 18 individuals (variable **P**opulation); a culture composed of either 10, 20, or 30 pieces of information (variable **C**ultural complexity); and, the pieces of information were distributed such that each person initially knows either 25, 50, or 75 percent of the pieces of information in the culture (variable percent **K**nown). This last variable, percent known, can be interpreted as the level of initial education. Neither these variables nor combinations of them are auto-correlated (see Table 1).

Table 1. Pearson Correlation Matrix

	<u>P</u>	<u>C</u>	<u>K</u>	<u>PC</u>	<u>PK</u>	<u>CK</u>	<u>PCK</u>
P	1.000						
C	-0.000	1.000					
K	0.000	-0.000	1.000				
PC	0.577	0.756	0.000	1.000			
PK	0.679	-0.000	0.679	0.392	1.000		
CK	0.000	0.756	0.577	0.571	0.392	1.000	
PCK	0.471	0.617	0.471	0.816	0.694	0.816	1.000

Note: These correlations are identical regardless of the type of communication scenario. For each type of communication scenario, the number of observations for Table 1 is 27.

Each society was examined under six communication scenarios. In the first scenario, one-to-one, all individuals in the society fall into the class "people." The innovator's message contains a single idea — the new idea. In the second scenario, 1 simple book, there are two types of agents — people and books. There is a single book, which contains only one piece of information, the innovator's new idea. All other agents in the society fall into the class people. The third scenario, 2 simple books, is like the 1 simple book scenario but with a second book that contains another innovator's new idea. In the fourth scenario, 1 complex book, there are two types of agents — people and books. There is a single book, which contains 5 pieces of information, the innovator's new idea and 4 other ideas known by the innovator and some other individuals in the society. All other agents in the society fall into the class people. The fifth scenario, 2 complex books, is like the 1 complex book scenario but with a second book that contains another innovator's new idea and 4 other ideas. In the

sixth scenario, one-to-many, all agents fall into the class "orators." In this case, the innovator's message is quite complex and contains all the information known by the innovator including the new idea.

As previously noted, the agents in these scenarios separate two important aspects of how communication technologies affect agent capabilities — the ability to learn and the ability to communicate to multiple individuals at once. In addition, the specific communication scenarios described vary along two other dimensions — competition and complexity. That is, in the 2 simple book, 2 complex book, and one-to-many scenario the mass-media agents implicitly compete with each other for the scarce resource "other individuals' time." Any individual having access to a one-to-one communication technology competes with others for a specific person's time, but since only two individuals can interact with each other at a time there is no competition for groups as in the case of mass-media. Further, in the (1 or 2) complex book and the one-to-many scenarios the message that is being simultaneously communicated is more complex. In these scenarios each of the "listeners" or "readers" may be learning something different from the "speaker" or "text." In the other scenarios each individual is learning exactly the same piece of information.

By setting up the societies in this way a 3x3x3x6 experimental design has been constructed. Each cell is a society uniquely characterized by its socio-cultural landscape and the classes of agents as defined by the communication technologies. A Monte Carlo approach is taken for estimating the mean of each cell. Each society examined was simulated 100 times thus making the variance within a cell negligible. Any measures of social change measured for a cell represents the average behavior across 100 societies. Due to processing constraints the behavior of each society was measured for 500 Time Periods. At this point, the vast majority, but not all, of all simulated societies had actually reached their ultimate state.

Measures of Socio-Cultural Change

Many different societal-level behaviors can be measured. I focus on those previously identified as being potentially affected by communication technologies; i.e., cultural homogeneity, consensus, and diffusion. As previously noted, communication technologies are expected to effect the rate at which the society achieves these factors. That is, a common suggestion is that mass-communication technologies enable the agent to communicate one-to-many and therefore will speed things up. Mass-communication should decrease the time to cultural homogeneity, the time to consensus, and the time it takes a new idea to diffuse,

relative to the time it would take if agents could only communicate one-to-one. In addition, one might expect that the more information that is available through mass-communication technologies (in other words, the higher the number of books, the more orators, and so on) the faster the society becomes culturally homogeneous and consensual. In other words, more information, more quickly communicated, will generate rapid cultural homogeneity and consensus. Or, one might expect that the more information that is available through mass-communication technologies the slower the society becomes culturally homogeneous and consensual. The argument is that increased information increases the competition among ideas for an individual's attention. This increased competition may mitigate any advantages gained by the increased speed of communication. Thus, one might also expect that as mass-communication becomes more prevalent particular ideas will diffuse slower due to the increased competition among ideas. One might also expect that the diffusion of a new idea is abetted by having agents who know only the new idea and cannot learn (i.e., simple books) as such agents cannot dilute the message. In contrast, one might expect that the diffusion of a new idea is abetted by having orators as they can learn the new idea and then rapidly disseminate it. Clearly, other expectations also exist. But notice that, when we consider only how communication technologies affect agent capabilities a series of, often contradictory, expectations seem to arise. We can examine these expectations, and locate a set of internally consistent expectations (in that they all follow logically from the same model) by utilizing the constructural model.

In order to precisely define measures of the rate of information diffusion, and the rate at which homogeneity and consensus are achieved, I use the following variables:

K — The number of pieces of information such that each piece is known by at least one agent in the society.

I — The number of individuals in the society.

$F_{ik}(t)$ — Whether individual i knows piece of information k at time t . $F_{ik}(t)$ equals 1 if i knows piece of information k at time t , otherwise 0.

V_k — The force of the piece of information k relative to the decision that is to be made. V_k equals 1 if the piece of information k suggests that the decision should be positive, -1 if the piece of information k suggests that the decision should be negative, and 0 if the piece of information k suggests that the decision should be neutral.

$B_{ij}(t)$ — Individual i 's actual decision (or belief) at time t .

$B_{ij}(t)$ — Individual i 's view of individual j 's decision (or belief) at time t .

As an aside, it is important to note that the proposed measures can be calculated either for each group or for the entire society. For comparability across all societies examined, I calculate these measures using only the individuals (i.e., societal agents capable of learning).

Diffusion

Diffusion occurs when a new idea discovered by one individual becomes known by others in the society. There exists a single innovator, an individual who discovers a new idea, in each of the societies examined. Initially, this idea is known only by the innovator. If the innovator is in a society with books the innovator may "write" a book that contains the new idea (and perhaps other information). Each Time Period the level of diffusion is measured as the number of individuals sharing at least one of the ideas the innovator places within the message.

Cultural Homogeneity

At each Time Period the level of cultural homogeneity is the average percentage of available information shared by any two individuals (see also Carley 1990, 1991). Mathematically, this can be stated as:

$$\text{Cultural homogeneity (t)} = \frac{\sum_{i=1}^I \sum_{j \neq i}^I \sum_{k=1}^K F_{ik}(t) \times F_{jk}(t)}{\binom{I}{2} \times K} \times 100.$$

Consensus

At each Time Period the level of consensus is simply the percentage of unique dyads having consensus. Consensus is defined using a fixed valuation scheme as defined below.

The underlying conception is that the individuals need to make a decision. This decision takes the form of an "answer" (yes, no, or neutral) to some "question." Each of the available pieces of information can influence this decision. Each piece of information provides support for either the affirmative decision, the negative decision, or no support. This support is defined as the valuation for that piece of information. These values are randomly distributed across the pieces of information such that 1/2 the facts have a +1 value and half have a -1

value. All individuals with access to the same information are expected to make the same decision (hold the same belief), thus the valuation scheme is constant across all individuals in the society. The individual's decision is determined for each individual as the sign of the sum of the information known by the individual weighted by the value of each piece of information. Mathematically, this can be stated as:

$$B_{ii}(t) = \begin{cases} 1 & \text{if } \sum_{k=1}^K V_k F_{ik}(t) > 0 \\ 0 & \text{if } \sum_{k=1}^K V_k F_{ik}(t) = 0 \\ -1 & \text{if } \sum_{k=1}^K V_k F_{ik}(t) < 0 \end{cases} .$$

Two individuals are said to concur at a particular time, just in case their decisions are the same. Consensus is thus measured as:

$$Consensus(t) = \frac{\sum_{i=1}^I \sum_{j=i+1}^I B_{ii}(t) = B_{jj}(t)}{\binom{I}{2}} \times 100 .$$

Over Time Performance

Let us first consider the behavior of each of these measures over time. In Figure 2, the over time behavior of a representative society is shown. These patterns are typical of all societies examined. That is, eventually, for the societies examined, all individuals will end up knowing all information that any one knows (Carley 1990, 1991a). Thus, eventually, cultural homogeneity, consensus, and diffusion will be 100 percent. Moreover, for all societies examined, regardless of the socio-cultural landscape or the communication technologies, the basic shape of the curves remains the same. What does vary across societies is the location of particular peaks and valleys and the time required to reach (or almost reach) the ultimate condition.

Given that the shape of the curve is the same, the operational question becomes at what time does the society reach (or almost reach) the ultimate condition.⁴ In this paper, the

following three over time measures will be used: (1) Time to Diffusion — the time at which 90 percent of the individuals share at least one fact with the innovator. (2) Time to Cultural Homogeneity — the time at which the average number of facts shared by any two individuals is 90 percent of the total number of facts. (3) Time to Consensus — the time at which 90 percent of the dyads have reached consensus.

These near-end measures are used, rather than the time until the ultimate condition occurs, for two reasons. First, ultimate measures can be afflicted by recalcitrant learners; i.e., the lone individual who is missing one fact and must wait until someone happens to locate this fact. Second, given the 500 Time Period cap the near-end value is a more accurate behavioral predictor.

COMMUNICATION TECHNOLOGIES: DETERMINANTS OF CHANGE

The results demonstrate that mass-communication does speed things up. In addition, the type of communication technology has other more subtle effects. These subtle effects will be examined, by first considering each of the three factors (population, cultural complexity, and percent known) separately. The results are displayed in Figures 1 through 3. In each of these figures, the time to cultural homogeneity, consensus, and diffusion are shown by plotting the average time for all societies with a given characteristic. For example, in Figure 1, we see that the average time to diffusion for all societies with a population of size 6 is just over 100. Recall, from the previous discussion that there are 54 ($3 \times 3 \times 6$) types of societies (each simulated 100 times) at each population level. The average is across all 5400 of these societies.

Essentially, the "pattern" that appears in these three figures is the same regardless of the communication scenario. That is, as the population increases the time to cultural homogeneity and consensus decreases, and the time to diffusion increases (Figure 1). As the complexity of the culture increases the time to cultural homogeneity, consensus, and diffusion increases (Figure 2). As the percent known by the individual increases the time to cultural homogeneity and consensus decreases, and the time to diffusion increases (Figure 3).

Figure 1. Impact of Population

Figure 2. Impact of Cultural Complexity

Figure 3. Impact of Education.

The communication scenario changes the time required to achieve the final condition. In Figure 4 the average time for each of the three measures given a particular communication scenario across all types of socio-cultural landscapes (27) is shown. As can be seen in Figure 4, things occur most quickly when all individuals in the society are orators. Just having a mass-communication technology available is not sufficient. Both competition among innovators having access to the mass-communication technology and the complexity of the information in the mass-communication affects how fast social change occurs. Mass-communication technologies can speed things up, but only under the right conditions.

Figure 4. Impact of Communication Scenario

Now let us consider interaction effects. Before examining the results, let us first consider the meaning of various interaction terms. The combination population * cultural_complexity reflects the number of possible socio-cultural ties that an individual can have. Population * percent_known reflects the probable number of individuals who will know a particular piece of information. Percent_known * cultural_complexity is the probable number of pieces of information initially known by each person. Finally, population * cultural_complexity * percent_known is the probable number of ties that each person initially has. In Tables 2,3 and 4 the regression coefficients are shown when the socio-cultural landscape variables are regressed on time to cultural homogeneity (Table 2), time to consensus (Table 3), and time to diffusion (Table 4). In each table the first column all societies are examined. The following 6 columns correspond to the 6 different communication scenarios. In these tables the results are due to performing a regression analysis on the mean for each type of society.⁵

Table 2. Predictors of Time to Cultural Homogeneity.

	<u>Overall</u>	<u>1:1</u>	<u>1 simple</u>	<u>1 complex</u>	<u>2 simple</u>	<u>2 complex</u>	<u>1:N</u>
R2	.904	.996	.997	.997	.997	.997	.998
P	-0.018	-0.035	-0.006	-.072	-0.071	0.060	0.030
C	1.766***	1.841***	1.837***	1.787***	1.847***	1.922***	1.793***
K	-0.004	-0.023	0.008	-0.066	-0.030	0.069	0.026
PC	-0.431*	-0.442***	-0.439***	-0.407***	-0.426***	-0.603***	-0.361***
PK	0.076	0.101	0.046	0.0118	0.151*	0.018	0.029
CK	-1.070***	-1.085***	-1.108***	-1.064***	-1.111***	-1.251***	-1.118***
PCK	.218	0.172	0.208*	0.188	0.218*	0.361**	.224*
N	16200	2700	2700	2700	2700	2700	2700

Note: *p < .1, ** p < .01, *** p < .001 (two-tailed)

As can be seen in Tables 2,3 and 4, what variables are significant when all cross-terms are taken into effect remain essentially the same across all communication scenarios. As the complexity of the culture increases it takes the society longer to reach cultural homogeneity. There is simply more for people to learn and so it takes longer before they all learn it. However, increases in the number of possible ties and the amount of information initially

known decreases the time it takes the society to reach cultural homogeneity. Essentially, the more possible ties, the more ways there are of potentially getting information and the higher the amount initially known the less there is for people to learn. The communication technologies slightly alter the strength of these relations, but leave them in tact. In addition, mass-communication technologies, particularly those which are more competitive and complex, strengthen the potency of actual ties, and in these cases the greater the probable number of ties each person has the longer it takes the society to become culturally homogeneous.

Table 3. Predictors of Time to Diffusion

	<u>Overall</u>	<u>1:1</u>	<u>1 simple</u>	<u>1 complex</u>	<u>2 simple</u>	<u>2 complex</u>	<u>1:N</u>
R2	.849	.987	.986	.994	.982	.998	.989
P	-0.079	-0.047	-0.150	-0.085	-0.050	-0.068	-0.104
C	0.598**	0.602**	0.381*	1.123***	0.259	0.889***	0.783***
K	-0.065	-0.002	-0.146	-0.101	-0.013	-0.087	-0.073
PC	0.166	0.065	0.331	-0.161	0.504*	0.058	0.203
PK	0.049	-0.047	0.107	0.097	0.015	0.066	0.108
CK	0.090	0.116	0.335	-0.295*	0.420	-0.088	-0.097
PCK	.171	0.342	0.100	0.343*	-0.054	0.199*	0.176
N	16200	2700	2700	2700	2700	2700	2700

*p < .1, ** p < .01, *** p < .001 (two-tailed)

As the complexity of the culture increases it takes longer for the innovative idea to diffuse. This is the dominant factor affecting diffusion. Basically, the more there is to know, regardless of the number of people who actually know each piece of information, or how many people share how many pieces of information, the longer it takes the new idea to diffuse. The fundamental factor at work is that in a highly complex culture there are more pieces of information implicitly competing for the attention of the individuals. The higher the cultural complexity the less likely the new piece of information will be communicated and so learned. Mass-communication technologies far from decreasing the effect of culture, actually increase the impact of culture. The more competitive and complex the communication scenario the greater the impact of culture. In addition, complex communication scenarios have a tendency to strengthen the benefits of education and the potency of ties. Specifically, when

these technologies are present greater knowledge breeds faster diffusion and greater social contact breeds slower diffusion.

As the complexity of the culture increases it takes longer for the society to reach consensus. However, increases in the number of possible ties and the amount of information initially known decreases the time it takes the society to reach consensus. Essentially, the more possible ties, the more ways there are of potentially getting information and the higher the amount initially known the more likely individuals are to not only learn faster, but learn the same things, and so concur. By and large, the communication technologies slightly alter the strength of these relations, but leave them in tact. However, when there is no mass-communication (one-to-one scenario) the more actual ties the longer it takes the society to reach consensus. Basically, under this scenario, people tend to group together with preferred interaction partner and so become more like the preferred partners and less like others. Mass-communication mitigates this effect and the impact of amount known is strengthened by having a communication scenario that admits complex messages.

Table 4. Predictors of Time to Consensus.

	<u>Overall</u>	<u>1:1</u>	<u>1 simple</u>	<u>1 complex</u>	<u>2 simple</u>	<u>2 complex</u>	<u>1:N</u>
R2	.905	.996	.996	.993	.996	.995	.995
P	-0.026	-0.015	-0.046	-0.063	-0.091	0.071	-0.015
C	1.376***	1.348***	1.271***	1.486***	1.377***	1.704***	1.438***
K	-0.027	0.005	-0.057	-0.049	-0.091	0.051	-0.035
PC	-0.348	-0.360**	-0.287*	-0.326*	-0.304*	-0.566*	-0.321***
PK	0.074	0.021	0.088	0.120	0.132	0.006	0.110
CK	-0.404*	-0.369**	-0.256	-0.469*	-0.347**	-0.633**	-0.479***
PCK	0.206	0.314*	0.214	0.128	0.149	0.251	0.242
N	16200	2700	2700	2700	2700	2700	2700

*p < .1, ** p < .01, *** p < .001 (two-tailed)

The potential impact of the competitiveness and complexity of the communication scenario has been alluded to. In Figures 5 and 6 the average time to cultural homogeneity, consensus, and diffusion are shown at each level of competitiveness and complexity. For competitiveness there is a 4 point scale range from no competition (one-to-one), slight

competition (1 simple or 1 complex book scenarios), moderate competition (2 simple or complex books scenarios), and strong competition (orator society). In Figure 5 the average time for each of the three measures given a particular level of competition present within a communication scenario across all types of socio-cultural landscapes is shown. For communication complexity there is a three point scale ranging from low complexity (the message contain only the innovative idea, i.e., one-to-one, and simple book scenarios), to moderate complexity (the message contains the innovative idea plus a few other ideas, i.e., complex book scenarios), and strong complexity (the message contains many ideas other than the innovative one, i.e., orator society). In Figure 6 the average time for each of the three measures given a particular level of complexity present within a communication scenario across all types of socio-cultural landscapes is shown. Examining Figures 5 and 6 we see that increases in the competitiveness or the complexity of the communication scenario enable the society to more quickly reach cultural homogeneity and consensus. Competitiveness and complexity also enable new ideas to diffuse faster.

Figure 5. Impact of Competition

Figure 6. Impact of Communication Complexity

DISCUSSION

In this paper, the relationship between communication technologies and the socio-cultural landscape was examined. The constructural model was adapted to examine the impact of communication technologies on social change. This adaptation was facilitated by thinking of technology as forming new agents and altering the information processing characteristics of other agents. This approach, far from personifying technology, is advantageous as it facilitates a systematic examination of properties of the technology and the agent. This approach makes it possible to study what Collins (1979) has termed the formal and informal means of producing culture.

In pursuing this analysis many important aspects of communication technologies were considered such as the one-to-many communication, competitiveness, the complexity of the message, and the ability of the agent to learn and so adapt its message over time. The value of the current study lies, in part, in that it demonstrates a systematic procedure for considering the impact of these and other characteristics of communication technologies within the framework of a dynamic model of individual and social behavior. Nevertheless, many aspects of communication technologies have not been considered. Such aspects include, but

are not limited to, the extent to which a technology serves to expand the agent's memory and thus mitigates any impacts due to forgetting, the extent to which the technology does not admit certain types of messages to be communicated, the extent to which the technology hides or makes ambiguous various status cues, and so forth. Future studies may consider these and other characteristics. Such studies would give us a better understanding of the factors affecting knowledge diffusion and cultural production.

Finally, the impact of communication technologies on information diffusion actually may be greater than that portrayed in this study. Herein, the measure of diffusion examines the time until 90 percent of the individuals learn all the ideas in the message. The more complex the message, the more that individuals must learn before we can say that the message has diffused. Nevertheless, message complexity leads to more rapid diffusion of a single novel idea. If the communication technology enables more complex messages the rate of diffusion may increase over that shown here.

CONCLUSION

This study suggests that simply having a mass-communication technology available is not sufficient for effecting positive social changes. Putting a new idea in print or making it available in a film, without tying it to the current culture actually makes it harder for individuals to learn the new idea. The "book" will simply grow dusty waiting for readers. The readers, having nothing in common with the book have no motivation to interact with it other than chance and so the new idea will languish. Making the book more complex, putting multiple messages in it, some of which are known already by at least some of the individuals in the society actually makes it easier for the new idea to diffuse. This is true even though different individuals may emerge from interacting with the book with different ideas. The reason is simple. The more complex the message, the greater the likelihood that a majority of the individuals in the society will recognize something in the message and so be willing to interact with it further. This, will increase the likelihood of the new idea diffusing. Moreover, such complexity facilitates the rapid emergence of cultural homogeneity and consensus. Mass-communication of a complex message simultaneously reinforces to multiple members of the society the information known already by only a few.

Ironically, competition for an audience speeds diffusion. The more books in print, the more films, the more radio shows the faster innovative ideas diffuse. Although it is not clear from the analyses run in this study such competition actually may be detrimental to the rapid emergence of cultural homogeneity and consensus as with each new competitor comes a

new idea and so an increase in cultural complexity. However, holding cultural complexity constant, as is effectively done in the one-to-many scenario, competition aids the rapid emergence of cultural homogeneity and consensus. Competition has this social advantage because in a competitive situation there is greater uniformity of access to the mass-communication technology and so greater ability to rapidly disseminate that information known by only one individual.

This study suggests that those factors which are beneficial in effecting the rapid emergence of cultural homogeneity and consensus are not necessarily beneficial for diffusion. Education and population benefit the development of cultural homogeneity and consensus but not diffusion. Communication technology, however, has a complex effect on diffusion. The dominant effect of mass-communication technologies on cultural homogeneity and consensus is to facilitate their rapid emergence. However, with respect to diffusion, communication technologies actually alter the impact of various structural factors. In multi-group societies this effect may be even stronger. Future research should examine this possibility. In this study, however, we see that new ideas diffuse more slowly the more ties there are when the message is simple, and these same ideas diffuse more rapidly the more ties there are when the message is complex. This suggests that models of diffusion have to be concerned not only with the learning process, but also with the social structure, the culture, and the communication technology. The approach taken in this paper is a step in this direction.

The results presented in this study are entirely consistent with the seeming inconsistencies discussed in the introduction. Mass-communication technologies can, when they are used to deploy complex messages, lead to a situation where different readers and different members of an audience may emerge with different knowledge even when the learning procedure is not fraught with interpretation and errors. Despite this lack of initial agreement, mass-communication can effect, as one hopes will occur in an emergency, more rapid diffusion of information. Moreover, such technologies can encourage the emergence of a common homogeneous culture. But such an effect is an eventuality. In the short run, mass-communication technologies can actually degrade cultural homogeneity and consensus.

NOTES

¹ This should not be interpreted as a complete list of assumptions necessary for building the formal model. In building the model many additional assumptions were made such as individuals do not forget, and the individual chooses randomly, with equal probability, from all information known to him or her when choosing a piece of information to communicate. Many of these modeling assumptions are not part of the theory per se but are expedients in creating a simple model consistent with the theory that enables one to engage in theory building. In contrast, the expanded list of assumptions should be viewed as assumptions of the theory itself.

² Kaufer and Carley (1993) discuss this in terms of the author's reach. They argue that communication technology, particularly print, by extending the author's information processing capabilities (which includes the ability to send, receive, analyze, and learn information) has extended the author's ability to reach an audience. Thus, print makes it possible for the author, because the author need not be physically present, to communicate with multiple people at once, communicate with more people, communicate simultaneously across a greater geographic area, and communicate across a greater span of time than is possible verbally.

³ The term book is being used in a highly general fashion to encompass any written material that is printed and mass-circulated such as newspapers and articles. Though each type of media would have slightly different properties, such as expected half-life, each admits the one-to-many communication and, as an artificial agent, is incapable of learning. These latter two properties being central to the results discussed in this paper.

⁴ For additional details on the impact of print-based technologies on the early portions of these curves see Kaufer and Carley, 1993.

⁵ When a regression is performed on the means rather than on the underlying population there are four main effects: (1) the coefficients are correct, (2) the standardized coefficients are slightly high, (3) the significance of the coefficients is underestimated, and (4) the fit of the equation (R^2) is slightly overestimated. In a regression on the means the dependent variable is a set of means such that the independent values are identical for all of the values averaged to create a specific mean. In this study the means were computed over 100 values. The central limit theorem applies. The standard deviations of the means are small and each mean becomes a highly reliable point estimate of the location of the true underlying distribution.

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