

Learning and Using New Ideas: A Socio-cognitive Perspective

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November 2000

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Citation: Kathleen M. Carley, 2001, Learning and Using New Ideas: A Sociocognitive Perspective. Ch. 6 in *Diffusion Processes and Fertility Transition: Selected Perspectives*, National Research Council, Washington DC, National Academy Press, pp. 179-207.

Learning and Using New Ideas: A Socio-cognitive Perspective

One of the key ways in which individuals garner new information is through their interaction with others. Sometimes, individuals act as passive receptors and like a sponge soak up new ideas, while at others times they actively seek new information. How individuals acquire and use such information is a function of both cognition and structure, the way they think and their position in the social world.. Recent research in psychology, sociology, cognitive science and communication theory has increased our understanding of the way in which individuals acquire and use information and the cognitive and social constraints on these processes.

It is useful to think about the acquisition and use of information as occurring within an interaction-knowledge network. From an individual's perspective the nodes in the network can be the various sources of information; e.g., other individuals, organizations, book, or news-shows. Most empirical studies, however, focus on networks with only one type of node individuals. In this network, the ties between the nodes can be any type of linkage; e.g., economic, advice, friendship, or social support. Again most empirical studies focus in on only a small set of these linkages. However, the reality is that individuals acquire and use information within networks composed of multiple types of nodes and organized through a multiplex of relations. At the node level, cognitive constraints on the way individuals process information affects behavior such as their ability to acquire and communicate information. At the tie level, structural constraints on the pattern of relations affects behavior. Most research focuses at either the node or the tie level. Recently, however, there has been some progress in understanding information diffusion from a combined cognitive and structural perspective.

Cognition and Information

It has become fairly common place for researchers in the behavioral and cognitive sciences to argue that human decision making is not rational. One form of this argument states that individuals are at least boundedly rational (Simon, 1976, 1979; Cyert and March, 1956, 1963; Carley and Newell, 1994; Carley and Prietula, 1994). The second form of this argument states that humans deviate in fairly systematic ways from the prescriptions of expected utility theory (Tversky and Kahneman, 1974; Ross, Amabile and Steinmetz, 1977; Kahneman, Slovik and Tversky, 1982). Research following from both of these paradigmatic arguments is informing our understanding of how individuals acquire and use information.

Humans as Boundedly Rational

To say that humans are boundedly rational implies both that they are cognitively limited in their ability to process information and that they are structurally limited in their ability to acquire and disseminate information. A great deal of research in cognitive psychology, social psychology and organization science points to the fact that individuals in making decisions, do not have full information and do not use all of the information that

they do have. For example, Feldman and March (1981) note that in organizations, most information that is collected is never used. They argue that information is often collected, particularly within organizations, simply to give others the appearance that one is acting rationally. Since, the control of and access to information are instruments of power (Branscomb, 1994), information collection and dissemination become a means of maintaining and exercising power. Consequently, issues of individual response to power and status differentials play a role in understanding whether people will acquire and use information from particular sources.

There are a wide range of findings about the specific way in which humans process information. A classic cognitive limitation has to do with memory: the primacy and recency effect. The basic idea is that individuals have a tendency to remember information they heard first and last and to forget the material in-between. Other cognitive limitations have to do with the complexity of the information (the classic 7+-2 rule) and the fact that if individuals chunk information (e.g., by using memory tricks and mnemonics) they can remember more. Cognitive limitations essentially slow the rate of information diffusion.

One of the most interesting cognitive limitations is the way in which individuals assess causality; specifically, individuals use a "covariation principle" to assess causality (Heider, 1958; Kelley, 1967). The covariation principle states that if event A accompanies outcome B, and if event A is absent when outcome B is absent, then people tend to attribute A as the cause of B. There is ample evidence that individuals see causality and correlation as going together. In particular, individuals seem to construct correlations to confirm their prior expectations about what causes what (Chapman and Chapman 1967, 1969). Individuals look for salient cues in suggesting causal links, rather than calculating them from the statistical occurrences (Taylor and Fiske 1978). In other words, individuals seek out obvious indicators of what they think should be causing some outcome and use such cues to make predictions about others. From an information diffusion perspective this means that individuals may incorrectly assume that the diffusion of a new birth control technique may have various beneficial or deleterious effects simply due to accidental temporal correlations.

Today, cognitive scientists are in the process of developing sophisticated models of cognition that are consistent with these and other known limitations. These models often take the form of computational models; e.g., ACTS-R and Soar (for a more detailed review see Pew and Mavor, 1997). A key element of each of these models is that for an individual, future action (including learning and use of new information) is a function of what the individual already knows. In these models, as individuals learn they alter their mental models and typically cannot reconstruct how they thought about a problem prior to getting the new information. This effect, referred to as hindsight bias, has been shown in empirical studies to cause individuals to be unable to reproduce the decision that they would have made prior to knowing the true outcome (Wasserman, Lempert and Hastie, 1991). Or in other words, it is difficult for people to judge ahead of time how likely they are to accept new information and to judge, after the information has diffused, whether they were originally predisposed to accepting that information.

Much of the recent work in cognitive science focuses on the relation between information, language and cognition (Hanson, 1990). Some of this work lies in the area of belief formation. In fact, there is a substantial literature on the role of messages in

effecting individual's attitudes and beliefs. For example, the work on reinforcement theory (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980; Hunter et al., 1984) and information processing theory (Hovland and Pritzker, 1957; Anderson and Hovland, 1957; Anderson, 1959; Anderson, 1971; Hunter et al., 1984; for a more complete review see Pew and Mavavavor, 1997). This work often focuses on how attributes of the message, message content, and the sender affects the receiver's beliefs. Numerous empirical studies provide empirical evidence linking belief change to message content. Some studies suggest that more established beliefs are more difficult to change (Cantril, 1946; Anderson and Hovland, 1957; Hovland, 1972; Danes et al., 1984). Additional studies demonstrate that (Whittaker, 1967; Insko, 1967; contain reviews): unless extreme beliefs are associated with more information, they are generally more affected by contradictory information; when neutral messages lead to a belief change, the change is typically that predicted by a discrepancy model; and belief shifts are in the direction of the message for non-neutral messages. Information, unlike a disease, is not simply learned through contact. Information diffusion, is not a contagion process but a complex socio-cognitive process. The likelihood of the diffusing information affecting behavior is a function of whether those others one comes in to contact with know the information (contagion), the extent to which those others have social influence on the receiver, and whether the message about the information is couched to support or disconfirm existing related beliefs,

Overall, much of the work that takes this approach to rationality is directed at specifying cognition at both a process and a knowledge level. Thus, issues of representation are as important as issues of process. The recent work on mental models is in this representational vein (Fauconnier, 1985). Additional process questions include: the role of emotions, speed and accuracy of response, and utilization of analogies (such as those used to comprehend time and distance). Much of this work has the potential to impact our understanding of communication and information seeking and usage behavior. However, further research is needed to illuminate this connection.

Humans as Deviates from Expected Utility Theory

Research in this area has focused on the way in which humans deviate from expected utility theory. Research in the past two decades has resulted in a number of findings about decision making in very context specific domains. For example, work in this area suggests that individuals view losses and gains differently (Kahneman and Tversky, 1979); that how the information is presented creates a framing effect that then influences the ultimate decision (Tversky and Kahneman, 1981); that decisions are often made on the basis of regret (i.e., what could have been) instead of the expected benefit (i.e., utility) of an outcome (Bell, 1982; Loomes and Sugden, 1982); that even minimal interaction leads to altruistic behavior (Orbell, van de Kragt and Dawes, 1988; Orbell and Dawes, 1993); and so on.

These deviations from expected utility theory are often referred to as biases or fallacies. Let us consider four of these: false consensus, representativeness, availability, and false uniqueness. The false consensus bias refers to the fact that most individuals tend to believe that others are like themselves (Dawes and Mulford, 1996; Dawes, 1989, 1990; Orbell and Dawes, 1993). Thus, people tend to over-estimate the degree to which their own past behavior, as well as their expected future behavior is truly diagnostic of

other individual's future behavior. Consequently, people will often assume agreement even when it does not exist, and so will fail to critically assess new information.

The representativeness bias refers to the fact that individuals often make decisions based on the similarity of the current situation (its characteristics and attributes) to a previous situation, rather than objective data (Tversky and Kahneman, 1974). This heuristic can cause individuals to believe in 'the law of small numbers'. Thus, people generally believe that random samples will resemble each other and the population more closely than statistical sampling theory would predict (Plous, 1993). When people use this heuristic they will typically ignore base rate information. A base rate is the relative frequency with which some event is seen in the general population. A consequence is that individuals will make decisions based on what the situation reminds them of, rather than on statistical likelihoods.

The availability bias refers to the fact that individuals often make decisions based on what information is most salient. People often assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind" (Kahneman and Tversky, 1974, p. 1127). This mental shortcut does not necessarily result in a biased judgment. However, it can when the information that is the most available is not the information that is most accurate due, for example, to recency or primacy effects.

The false uniqueness effect refers to the fact that individuals often rate themselves as better than others (Fiske and Taylor, 1991). For example, when asked to rate themselves on some task, such as driving ability, most people tend to see themselves as better than average. Most people, when asked to rate their contribution to a group tend to view themselves as one of, if not the, strongest contributor. And so on. This possible over-rating of self is seen as related to a need by the individuals to think of their abilities as relatively unique (Marks, 1984; Kernis, 1984). An interesting point is that while most individuals see their abilities as unique (and better than average) they see their opinions as shared by others (false consensus). Consequently, for matters of opinion individuals may be less likely to seek information from others simply because they assume that they will not learn anything new.

Uncertainty and Stress

Human beings are not only not rational but most classical models of individual decision making provide little guidance for how people actually use information and make decisions in most settings (Connolly, 1993). The work on individual decision making under stress and uncertainty comes out of both approaches to rationality, and draws on work on decision making in naturalistic settings. Collectively, this work suggests that individual differences and the context are both important determinants of how individuals acquire and use information when faced with uncertainty. Cognitive biases, personal characteristics and various sources of uncertainty combine to affect the way in which individuals use the information they acquire (Fischhoff et al, 1981; MacCrimmon and Wehrung, 1986). Fischhoff *et al.* (1982) suggest that when individuals must make a decision in an uncertain situation their decision will be affected by: (1) uncertainty about the nature of the problem; (2) difficulties in assessing the facts; (3) difficulties in assessing the values; (4) uncertainty about what other people will do, think, or believe; and (5) difficulties in assessing the quality of the decision.

In general, people differ in the way in which they cope with new information and events, particularly those that induce stress (Thotis, 1991). Differences in coping styles cause people to want, and possibly to need, different information when confronted with stressful events (Miller, 1995). Emotional states, such as depression, can alter individuals' information seeking and giving behavior (Alloy, 1988). An individual's affective state can impact the extent to which an individual sees a situation as stressful and stress can alter an individual's affective state. This complex interaction between stress and affective state in turn impacts how an individual searches and uses information. Moreover, people respond to others, at least in part, at an affective level (Heise, 1979; Heise and McKinnon, 1987; Smith-Lovin 1987a, 1987b). Thus information is interpreted differently, is likely to be remembered differently, and will be sought differently depending on the affective basis of the interaction. For example, some researchers argue that individuals hold attitudes or beliefs because they meet particular psychological or affective needs (Katz, 1960; Herek, 1987); hence, erroneous beliefs might be held regardless of the amount of information learned because they reduce stress or increase feelings of self esteem.

One of the current theoretical perspectives, naturalistic decision making, argues that individuals make decisions on the fly often employing analogies with earlier events. Klein (1993), a leading proponent of this theoretical approach, has suggested a model of decision making in which the individual's first action is to recognize the linkage between the current event and something previous. This recognition primes the decision process and influences the subsequent outcome. Klein suggests that particularly under time stress, this is the key to the way in which people make decisions. From a naturalistic perspective, reasoning from argument and from case examples are the dominant ways in which individuals use information.

From the communication side, research has shown that not attending to the needs of the target audience can reduce the likelihood that they will retain the information provided and decreases the likelihood that they will pass it on. For example, Mita and Simmons (1995) after examining the diffusion of family planning information to young unmarried women in Bangladesh argued that to be effective the communications needed to pay greater attention to the contraceptive needs of young women. The principle underlying this is the that of immediate comprehension (Carley, 1986). The likelihood of a message being comprehended and remembered increases if the message is directly related to information already known by the receiver. Essentially, for most information receivers, the information provider to be really effective needs to make the link for the receiver between the new information and what the consumer already knows and wants to know. This decreases processing time on the part of the receiver and allows them to focus in on the new information.

Groups and Cognition

Researchers interested in cognition have also examined how being in a group or team affects cognition. Both theoretical and empirical work suggests the existence of information processing effects at the group level (Cannon-Bowers and Salas, 1990; Salas, Stout, and Cannon-Bowers, 1994; Innami, 1992; Walsh and Fahey, 1986). This work has had a wide range. Three different issues that have been addressed are particularly

important from a diffusion perspective: group think, distributed cognition, and transactive memory.

It is often argued that collections of individuals engage in group think (Janis, 1982). Groupthink is the tendency of groups to converge on ideas and to sanction aberrant ideas in such a fashion that important information may be ignored and erroneous decisions may be made. Groups also tend to polarize; that is their decisions are more extreme than the average decision of the group members (Pruitt, 1971a, 1971b). Thus, groups tend to make decisions that are much more or much less risky than would the individuals in isolation (Pruitt, 1971a, 1971b). From a diffusion perspective, what this means is that learning new information in a group setting can cause the individuals to mis-estimate its importance and either over or under-attend to the new information. Recent work in this area suggests that these group behaviors may be a function of both the initial distribution of information, beliefs, attitudes, and decisions as well as the underlying network connecting group members (Friedkin and Johnson, 1990; Friedkin, 1991; Rice, 1993).

From a distributed standpoint, groups have an intelligence that is outside of the cognition of the individual members. Accordingly, group intelligence lies, in part, in the way in which information is distributed across group members and the linkages among group members. The work on distributed cognition suggests that groups and organizations as computational units are able to collectively represent and solve problems in ways that go beyond the cognitive abilities, knowledge, and possibly even awareness of the individuals in the group (Hutchins, 1995). The communication structure in the group is seen to influence the computational approach of the group to problems and the resultant decision (Carley and Svoboda, 1996).

Transactive memory refers to the ability of groups to have a memory system that exceeds that of the individuals in the group (Wegner, 1987; Wegner, Erber and Raymond, 1991; Moreland, in press). Related ideas are joint remembering (Edwards and Middleton, 1986) and group remembering (Clark and Stephenson, 1989). Research on transactive memory, like that on distributed cognition, relies on the idea that knowledge is stored as much in the connections among individuals as in the individuals. Wegner developed the theory (Wegner 1987) and an associated computational model (Wegner, 1995) at the dyadic level by drawing on work in computer science he argues that processing factors that are relevant when linking together computers (such as directory updating, information allocation, and coordination of retrieval) are also relevant when linking together the memories of humans into a group memory. Empirical research suggests that the memory of natural groups is better than the memory of assigned groups even when all individuals involved know the same things (even for groups larger than dyads, Moreland, in press). Further, Moreland, Argote and Krishnan (1996, in press) have shown that transactive memory tends to improve group performance. And groups of individuals who train together tend to have better recall of how to approach problems than do groups where the individuals train separately (Liang, Moreland and Argote, 1995). Collectively, this body of research suggests that for individuals and especially for the group, knowledge of who knows what may be as important a determinant of group performance as task knowledge.

Social Structure and Information

Individual cognition is an important determinant of the way in which individuals acquire and use information. However, as hinted at by the work on transactive memory, cognition is not the sole determinant of information based behavior. One reason for this is that there is a difference between "reality" and reality as perceived by the individual (Cooley 1902; Mead 1962; Festinger 1954,1957). Reality as perceived by the individual is often a function of their position in the underlying social network. This point is eloquently made by the decades of research on social structure which has repeatedly demonstrated that individual's beliefs, attitudes, knowledge, and actions is as much a function of who is known as it is of what is known and that the underlying social structure is critical to the diffusion process (Rapoport, 1953; Katz, 1961; Rogers, 1995). This research has led to a more thorough understanding of the way in which the underlying social network influences individual, group, organizational and community behavior (Wellman and Berkowitz, 1988[1997]). Collectively this work has repeatedly shown the influence of who you know, and the position of the individual in the network on the individual's consequent actions.

Studies of information diffusion have demonstrated the utility of the social network approach and the value of many of the network based measures for understanding diffusion (Coleman et al., 1966; Burt 1973, 1980; Valente, 1995; Morris, 1994; Carley with Wendt, 1991; Friedkin, 1993). These studies suggest that what information the individual has, what decisions the individual makes, what beliefs the individual holds, and how strongly the individual holds a belief are all affected by the individual's social network. A variety of network effects, such as whether or not the individual is peripheral or central in the network, the number of other individuals communicated with, the strength of the relationship with those other individuals, whether the tie is embedded in a triad, and the symmetry of the relationship, play a role in the way in which individuals acquire and use information. For example, central individuals (those connected to more others) are in a better position to acquire new information (Freeman, 1979; Weenig and Midden, 1991) and are more likely to have access to novel information (Valente, 1995). The higher the level of network cohesion the higher the level of communication about the issue of concern (Friedkin, 1993). More peripheral individuals may be more likely to act upon novel information or to generate innovations (Burt, 1973, 1980; Lin and Burt, 1975). Individuals who are more central may be over-constrained and so unable to act on novel information, particularly if they are embedded in a large number of triadic (Simelian) relations (Krackhardt, 199a, 199b). Such individuals are so constrained by being involved in a large number of triadic relations that owing allegiance to all can act for none.

From an information diffusion perspective, the literature clearly shows that different factors influences the diffusion of ideas and technologies. For example, institutional constraints (Strang and Meyer, 1993), cost and network externalities such as how many people use a technology are important determinants of technology adoption (Kraut, Rice, Cool and Fish, 1997). However, cost in particular has less to do with the diffusion of information. Herein, the focus is primarily on the diffusion of ideas. Research in this area has a long tradition (Festinger, 1948; Allen, 1977; Cole and Cole, 1973; Valente, 1995). Researchers have examined the diffusion of many different types of information including: rumors (Festinger, 1948, 1950), job openings (Granovetter, 1974), scientific information (Price, 1965a, 1965b; Carley, 1990), and technological information (Allen, 1977), and information about family planning (Valente, Watkins, Jato, Van der Straten and Tsitol,

1997). Collectively, this research has led to a number of findings. For example, information flows more quickly in integrated groups (Coleman et al., 1966), but only if the groups are relatively small and have relatively simple cultures (Carley 1991; Kaufer and Carley, 1994). Individuals are often more willing to seek group threatening information (such as information about new jobs) from individuals with whom they have little regular contact (weak ties) (Granovetter 1973, 1974). Altering the communication technology can alter the flow of information and so the overall performance of the group (Rice, 1994). Whether information flows from one group to another depends on both the degree of interaction within the two groups and the degree of interaction between the two groups (Kaufer and Carley, 1994). Although information diffuses through networks, the likelihood that the information will actually diffuse to a specific individual depends on the number of network ties (Weenig and Midden, 1991). Although information diffuses through networks, the likelihood that the information will actually diffuse from one group to another, and the speed with which it will diffuse, depends on the heterogeneity of each group and the number of ties or boundary spanners between the two groups (Kaufer and Carley, 1993).

The underlying social network influences what information the individual acquires, how that information is used, and the way that information is filtered into terms affecting individual choice. In other words, social networks have both a social learning and a social influence effect (Montgomery and Casterline, 1996). Social learning involves the acquisition of information from others. In this case, the individual's position in their social network, the who talks to whom influences diffusion. The information that is learned might have to do with what new technologies are available, with who uses what technology, or with the health, social, political and economic consequences of various choices. The information need not be accurate and may encompass beliefs. Social influence is the weight of authority, deference, reciprocity and social conformity pressures that individuals place on each other. The individual's position in their social network and the opinions held by those in their network collectively influence the individual's opinion (Friedkin and Johnson, 1996).

Recent work on contraceptive use demonstrates the myriad of ways in which the underlying social network affects choice (Entwistle and Godley, 1998). In a study of Cameroonian women, Valente et al. (1997) demonstrated that individuals who were advised to engage in a behavior by their network were more likely to engage in that behavior. Further, an individual's perception of how his or her network will respond to a situation is an important determinant of the individual's behavior regardless of whether the individual's perceptions are accurate (Valente, et al., 1997). Nevertheless, while an individual's network position may affect whether or not the individual hears about an innovation, the position itself may not determine adoption of the innovation. In fact, research on diffusion networks has found mixed support for the claim that network exposure increases adoption (Valente, 1995). A person's network exposure is the proportion of others in the individual's personal network that are themselves adopters. Consequently, although network position is perhaps the primary determinant of what information the individual acquires, it is only one of the determinants of how the individual uses that information and what actions are subsequently taken. In terms of information usage, a variety of factors are critical including personal characteristics, cognitive processing abilities and biases, the individual's network position, the

individual's perception of his or her network, and the consequent influence of others on one's actions.

In most societies there are multiple types of ties that link individuals (e.g., see Sampson, 1968; Roethlisberger and Dickson, 1939). This is referred to as multiplexity (White, Boorman and Breiger, 1976). Such ties include socio-emotional ties such as friendship, instrumental ties such as advice giving and money lending. Different types of ties are often used to access different types of information. Moreover, individuals receive not just different information, but different types of social support through different ties (Wellman, 1992; Wellman and Wortley, 1990; Wellman and Gulia, forthcoming). Such ties have both a direct affect on the individual's information gathering ability (changing what information is accessible) and an indirect affect by influencing the degree of social support which influences the individual's mental health and affective state which in turn affects the individual's propensity to seek information and the way in which information is interpreted once it has been found.

One question is whether such multiplexity enhances or constrains the flow of new ideas. The stronger the multiplex of relations that connect two individuals the more likely they are to find it easy to communicate and to have a host of shared experiences on which to base their communication; and, the less likely they are to know information not known by the other. For example, if the individual is seeking out sensitive information, or information that not commonly known by the group then weak ties may be key. This is known as the weak tie hypotheses (Granovetter, 1973). Further, different types of information flow through different ties. As a trivial example, work related information rarely flows through kinship ties. Thus, highly multiplexed relations may actually inhibit the flow of new ideas, particularly for ideas originating outside of the group. For getting new information non-symmetric relationships may be key. In particular, individuals are more likely to seek out and try to acquire information from those with whom they are relatively more similar even if those others do not seek them out (Carley and Krackhardt, 1996).

An important factor in information diffusion may have to do with whether individuals are information seekers or passive receptors of information. Although it may be difficult to disentangle the two (Leenders, 1997). In the seeking model, individuals are information processors who actively seek information. According to the seeking model the resultant distribution of information is dependent on the goal orientation of the individuals. Information seeking behavior is not viewed as random but subject to constraints and the topology of the social space. Due to time and resource constraints individuals seek information using channels with which they are familiar. Moreover, channel characteristics (weak or strong ties) appear to affect what information is sought, and the success of that search (Granovetter, 1973; Granovetter, 1974). Motivation then affects the way in which the channels are used; but not, whether or not the social structure bears a relation on diffusion. A variant on the information seeking models is the utility maximization models. Here individuals interact because doing so is expected to increase their utility (Durlauf, 1996).

Social networks are not static but change over time, often dramatically (Weesie and Flap, 1990; Doreian and Stokman, 1997). However, only a few models exist for predicting this change (Holland and Leinhardt, 1977; Sanil, Banks and Carley, 1995; Banks and Carley, 1996). Much of the work on network evolution has focused on change

in friendship networks (Johnson, 1986; Carley and Krackhardt, 1996; Zeggelink, 1993, 1995, 1996). This work shows that networks are incredibly homogenous (that is most people in an individual's network are of the same gender, race, educational level, etc. Further, as networks of friends evolve the overall network of individuals becomes organized into a set of self-reinforcing groups (Zeggelink, Stokman and van de Bunt, 1996; Stokman and Zeggelink, 1996). That individuals when under stress tend to drop individuals with whom they have less in common and are more weakly tied (Behrens, 1997). An important source of change in underlying social networks is change in the distribution of information. Such cultural level changes can be a function of technology.

Technology and Information Diffusion

Communication technologies play an important role in getting information to people (Valente et al., 1994). Gantz, Krendl and Robertson (1986) in discussing a local news event noted that 80% of the subjects first heard of the event through interpersonal sources. However, in terms of follow-up details, the mass-media quickly assumed a dominant role as the primary diffuser of information. Print, and indeed any communication media that encapsulates the views of the author increases the author's reach and so makes possible the wider and more rapid spread of information (Kaufer and Carley, 1993; 1994; 1996). The mass-media often becomes the primary source of details on new information because of its one-to-many capabilities and its ability to transmit an encapsulated message with less change in that message. Nevertheless, at an individual level, different types of people will choose to communicate their ideas by different media (Haythornthwaite, Wellman and Mantei, 1995).

Communication technologies are not guaranteed to increase the extent to which individuals are informed. Telecommunication technologies have often been touted as the mechanism by which the knowledge gap across people will be reduced. However, recent research suggests that it is possible that such technologies will simply create an information elite and that under such technologies the knowledge gap will widen (Alstyne and Brynjolfsson, 1995, 1996; Carley, 1995, 1996). Moreover, such technology can increase competition among ideas leading to overload rather than clarification (Carley, 1996; 1995). Changing access to technology can alter the underlying network structure and so alter who is likely to have access to what information (Alstyne, 1995; Carley, 1995, 1996) and can thus change the distribution of power (Barley 1990; Butler and Gibbons, 1997).

Perhaps the most important feature of the new tele-communication technologies is that they are a source of both information and social support (Hiltz and Wellman, 1997). New communication technologies can have substantial social, and even psychological, consequences as they alter the way in which individuals acquire and use new information (see for example, Price, 1965b; Rice, 1984; Sproull and Kiesler, 1991). For example, technologies such as email can reduce social status cues and increase anonymity thus facilitating the acquisition of novel and stressful information (Sproull and Kiesler, 1991). Communication technologies which enable some of an individual's ideas to remain intact and unchanged over time, and to be communicated without the individual being present facilitate communication at great geographical and temporal distances (Kaufer and Carley, 1993). In fact, one of the reasons that technology is expected to have such a profound

effect on the redistribution of knowledge, networks, and power is because the technology is expected to overcome the profound influence of physical space.

Physical Space and Information Diffusion

One of the most prevalent findings in the communication of information and the consequent impact of that information is that distance matters. Physical distance impacts information diffusion in both at a micro level (diffusion within the same organization or living complex) and at a macro or societal level (diffusion across a country or between countries). At the micro level, people tend to interact more with those to whom they are proximate (Allen, 1977; Latane et al. 1995). People are more likely to be influenced by the attitudes of those to whom they are proximate (Rice and Aydin, 1991). In fact, communication bridges that increase the physical proximity among people are thought to be critical to successful innovation (Allen, 1977). Entwisle et al. (1996) found that village location and placement of family planning services had a critical impact on patterns of contraceptive choice.

Latane, et al. (1995) found that the physically closer in space two individuals are to each other the more frequent are the interactions that they recall. Results suggest that the relationship between distance and interaction frequency may be describable by an inverse power law with a slope of -1. At the societal level, spatial factors also affect the flow of information between nations and organizations (Strang and Tuma, 1993). Geographers have worked on the problem of diffusion and spatial models for a long time (for a review of this work see Abler, Adams and Gould, 1971). Modern GIS systems and new statistical techniques for taking location into account are providing a better understanding of the spatial determinants of position. Computational multi-agents models using spatial positioning can now be used to develop veridical theories of the impact of location on information diffusion and choice. Further, the new GIS systems may ultimately enable analyses such as that conducted by Entwisle et al. (1996) to become more economically feasible.

Recent work in this area is suggesting that it is not physical space per se that may be important but perceived distance. In particular, low cost telecommunication options are providing individuals with the opportunity to create physically distant socio-emotional support networks. In other words, electronic groups are beginning to look like virtual social networks and provide information and support needs (Wellman, 1997). This can be an important source of information for individuals, particularly for information about rare events and new technology. The presence of computers and access to the internet could become a key determinant of the patterns of contraceptive choice in countries with otherwise low access to telecommunication technology.

Recent Advances Linking Structure and Cognition

An information processing perspective links much of the work on both cognition (Reitman, 1965) and information diffusion (Rogers, 1995). However, there are few theories, let alone formal models, that consider the joint role of cognition and structure on information diffusion. The work in this area tends to focus on diffusion in one of two ways: linking individuals differences and social position or linking culture and social structure.

Individual Difference Perspectives

Numerous studies have provided ample empirical evidence that social pressure, in terms of what the individual thinks others believe and normative considerations, affect individual's attitudes (Molm, 1978; Humphrey et. al., 1988; Fulk 1993 for example). The plethora of research on these social processes and pressures has led to a number of different theories about the way in which individuals process and use social information including: social comparison theory (Festinger, 1954), social learning (Bandura, 1977), social information processing (Salancik and Pfeffer, 1978; Rice and Aydin, 1991), and social influence theory (Friedkin and Johnson, 1990). Most theories posit a simple process by which individuals interact with a small group of others, learn their attitudes or beliefs, weight this information by their network ties to these others, and then alter their beliefs (e.g. Rice and Aydin, 1991; Fulk 1993; Rice, 1993). In the demographic research, individual perceptions and beliefs are conspicuously absent (Montgomery, 1997; Montgomery, 1999). New models of individuals perception of fertility and the risk of conception are needed that take a social learning perspective in which individual differences are accounted for are needed (Montgomery and Casterline, 1996).

Valente's (1996) threshold model of diffusion posits a role for both cognition (in the form of individual differences) and structure (in terms of relational influences) in determining the acquisition and use of information. In this model, each individual has an internal threshold for accepting or acting on new information that depends on the type of information and possibly individual psychological traits such as the need for acceptance (Valente, 1995). This threshold can be interpreted as the number of surrounding others who need to accept or act on a piece of information before the individual in question does. There are two unique features to this model. First, it enables researchers to compare relational vs. structural influences by varying parameters of social influence (near vs. distal others, relational vs. structural weighting). Second, this model demonstrates that individuals, or other adopting units, vary in the amount of social influence needed for them to adopt.

Interestingly, this literature has also shown some support for the idea that individual's personal characteristics influence the likelihood that they will discover new information (e.g., journals read Allen, 77). However, the overall context may affect what self image is evoked and so how the individual responds to information (Ridgeway and Smith-Lovin, 1996). In particular, as was previously discussed, the individual's emotional state affects the access to and use of information.

Cultural Perspectives

Cognition and culture are inextricably woven together (Carley, 1991; Hutchins, 1995). The pattern of communication among individuals creates both a joint cognition and serves to alter culture (Kaufer and Carley, 1993; Hutchins and Hazlehurst, 1991). Current work in this area is being carried out through computational analysis. Computer simulations of groups jointly working, exchanging information, and communicating are used to explore how individualized cognition and connections among individuals can work together to lead to the emergence of social change, new social structures, and social cognition. As individuals interact and exchange ideas, beliefs, and attitudes the underlying socio-cultural environment changes. Subgroups (Carley, 1991) and subcultures form (Latane and Bourgeois, 1996). Certain beliefs come to dominate (Krackhardt, 1997; Boorman and

Levitt, 1980). There are three basic approaches that are being examined: spatial basis, cultural connections, and socio-biological approach. All three approaches draw on the fact that empirical evidence demonstrates that over time through interaction group members become more alike and their attitudes and beliefs become correlated (Latane and Bourgeois, 1996). And, all three approaches assume some form of dynamics.

The first approach examines the interaction between structure and cognition by focusing on interaction exchange among actors who are structurally constrained by their physical position in a space. A key feature of this approach is that individuals tend to be more influenced by those who are physically nearby. Thus spatial factors which influence who interacts with whom can give rise to locally consistent patterns of shared attitudes, meaning, and beliefs. An example of this approach is Latane's dynamic social impact theory (DSIT) suggests that individuals who interact with and influence each other can produce organized patterns at the group or unit level that serve as a communicable representation which can be identified by others (Latane, 1996; Huguet and Latane, 1996). Latane (1996) uses an evolutionary approach to suggest ways in which communication can lead to change in attitudes as individuals develop cognitive bundles of information that then become distributed through the social space. A similar approach to Latane's is taken in the work on A-Life by Epstein and Axtell (1996). A simplified version such theories can be modeled as a game of artificial life. Actors are laid out spatially on a grid. Actors can interact with those nearest (e.g., those to the North, South, West, and East). Individuals begin with one of two competing messages or attitudes or beliefs. These diffuse simultaneously. Generally, these two beliefs are treated as being in opposition and an individual cannot hold both simultaneously. Initially beliefs may be distributed randomly; however, over time, actors come to hold beliefs similar to those near them.

The second approach assumes that actors structure their own space by forming and reforming connections among themselves as they interact and exchange information while doing some tasks. A key feature of this approach is that part of the intelligence of the society is thought to reside in the pattern of connections among actors and not just within the minds of the actors. An example of this approach is constructal theory (Carley 1990, 1991, 1995; Kaufer and Carley, 1993). Constructal theory posits that both the individual cognition and the socio-cultural environment are continuously constructed and reconstructed as individuals concurrently go through a cycle of interaction, adaptation, and motivation which moves them through an interaction-knowledge space (Carley, 1991). According to the basic formulation individuals engage in a fundamental interaction-shared knowledge cycle in which individuals provide information to and receive information from those with whom they interact thereby irrevocably altering their future interaction and communication behavior. According to this theory, the concurrent actions by individuals necessarily leads to the co-evolution of social structure and culture because it leads to the redistribution of information. And interaction partners across the actors (Carley, 1999). Accordingly, the rapidity with which a new idea diffuses, consensus forms, and cliques form are all functions of the innovators position in the socio-cultural environment. The innovators position changes over time as new ideas diffuse, consensus forms, and cliques form and uniform. A consequence is that very minute initial differences in the underlying socio-cultural configurations may facilitate or hinder information diffusion and consensus formation. Communication technologies affect

which socio-cultural configurations best facilitate information diffusion and consensus formation, because they affect the properties of the actor and the way in which the actor can engage others in the exchange of information. A second consequence is that what norms or social biases the group, organization or society form may well be the result of the relative rate of change in information diffusion, consensus formation and clique formation (Carley and Hill, 1999).

According to the constructural perspective beliefs and attitudes mediate one's interpersonal relationships through a process of "social adjustment" (Smith et al., 1956; Smith, 1973) and social structure affects what attitudes and beliefs the individual holds (Heider, 1946) as well as other behavior (White et al., 1976; Burt, 1982). It follows that if those with whom the individual interacts hold an erroneous belief then the individual can become convinced of the erroneous belief despite factual evidence and will in turn persuade others. For controversial information, such as beliefs, what belief dominates is a function of the size of the population and the extensiveness of the underlying information. Consequently, large information poor groups can become dominated by erroneous beliefs. For example, in information poor group, such as members of a third world country, an erroneous belief may persist, such as a belief that there is high infant mortality even after the mortality rate has declined. Since the perception of mortality declines are related to fertility declines (Montgomery and Casterline, 1998) an underlying constructural process which results in lagged mortality perceptions may be at the root of delayed changes in fertility related behavior.

The third approach draws on the work in socio-biology to argue for a joint structural and behavioral basis for information transfer (Krackhardt, 1997; Boorman and Levitt, 1980). The basic idea is that the diffusion of controversial information, like beliefs, is a socially determined phenomenon. Thus, when there are competing beliefs, whether an individual holds a belief depends not just on what they know, but also on whether or not those surrounding them also hold that belief. Social change and the dominance of particular beliefs is a function of the social structure (number of groups, size of groups, pattern of connection among groups, mobility between groups, and initial distribution of beliefs) and individual differences (likelihood of an individual changing a belief as he or she encounters others). There are three main findings from this research. First, in a large undifferentiated society, no controversial innovation can survive unless it begins with a large proportion of believers in the innovation. Second, there are structured conditions under which even a very small minority of innovators can take over a large society. And finally, once the innovation has taken hold across the society, it is virtually impossible for the pre-innovation state to recover dominance in the organization, even if they begin with the same structural conditions that the innovators enjoyed.

Toward a Socio-Cognitive Approach to Information Diffusion

Communication theorists typically argue that the individual who receives a message changes his or her attitude toward both the subject of the message and the individual from whom they receive the message as a function of the message (Hunter et al., 1984). Empirical evidence supports this contention. Thus, information diffusion is both affected by and affects what individuals know and whom they know. Cognition and social structure become linked in a dynamic cycle in which the communication of information alters the underlying cognitive and social structures. Thus policies seeking to aid or

inhibit the diffusion of particular information need to consider not just the foibles of human cognition, not just the underlying social networks of the relevant individuals; but also, the basic dynamic processes through which the social networks and knowledge co-evolves.

Some theories of the fertility transition take diffusion effects into account. Following Montgomery and Casterline (1996) in the most sophisticated of the diffusion models both social learning and social influence are considered. When this is done, the models fit the empirical data better and enable an explanation for why fertility choices lag mortality decline. In particular, simple simulation models demonstrate that as the size of the individual's network and the extent to which they are influenced by others increases information converges faster and there is consequent greater homogeneity in choice (Montgomery and Casterline, 1998). However, even in these models the social network is decoupled from learning. That is, the network is treated as static.

The brief summary provided in this paper suggests that choice is a function of both the social network and human cognition. At a minimum, this means that the diffusion process can be better characterized by taking into account both what the individual knows and who the individual knows. More than this, however, recent work, both empirical and theoretical indicates that the social and the cognitive are linked. To make clear the relations it is worth thinking in terms of four constructs: people, knowledge, locations, choices. This defines a set of networks (see table 1). What this summary has indicated is that each of these networks play a role in affecting fertility related behavior. Most studies, however, have considered only a couple of cells in the meta-matrix at a time, and kept the others fixed. For example, the Montgomery and Casterline (1998) model diffusion and choice (thus the knowledge network and choice network), keep the social network fixed, and ignore all other networks.

Table 1. Meta-Matrix of Networks and Choice				
	People	Knowledge	Location	Choice
People	Social Network	Knowledge Network	Physical Network	Choice Network
Knowledge		Information Network	Community Network	Decision Network
Location			Geographic Network	Voting Network
Choice				Tradeoffs Network

There are two key advantages to the diffusion models that have been used in social and organizational studies over those currently used in fertility studies. First, in some of these models the social network and knowledge network co-evolve; neither is taken as fixed. This enables the long run consequence of policy interventions to be more completely evaluated. Second, in these models the agents are heterogeneous; i.e., they vary in terms of their social, knowledge, physical and choice networks. Human networks are quite heterogeneous. For example, some people cite less than five people they talk to about health matters while others cite dozens. The impact of influence will vary based on

the size of their individual networks. Thus, multi-agent models that capture this heterogeneity may afford better predictions and more accurate estimates of the impact of policies.

Multi-agent models where the agents interactions are constrained by where they are physically located in space, their social networks, what they already know, the choices they need to make, and the available telecommunication technology hold out a promise for improved theoretical understanding of the diffusion process.

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