4-8483 — 5/26

Penn State ILL Lending - ARTICLE

ILLiad TN: 423885

Journal Title: Diffusion processes and fertility transition ; selected perspectives /

Volume:
Issue:
Month/Year: 2001
Pages: 179-207

Article Author:

Article Title: Kathleen Carley; Learning and Using New Ideas; A Sociocognitive Perspective

Notes: Borrowing Notes; ARIEL 128.2.114.135
****New as of 8/26/04****

From:
Penn State Interlibrary Loan Lending
127 Paterno Library, Curtin Road
University Park, PA 16802

Fax: 814-863-2653
Ariel: 128.118.152.188

5/26/2005

Request in processing: 20050525

Call #: HQ766.5.D44D54 2001

Location: Paterno - 2nd Floor

ILL# 5541767

Ariel: 128.2.114.135

Patron Economou, Rochelle

PMC

PA Academic

MAXCOST:$35.00IFM

Ship To:
Engineering and Science Library, ILL
Carnegie Mellon University IDS#187 A01
5000 Forbes Avenue
Pittsburgh, PA 15213-3890

Fax: (412)681-1998

Valente, T.W., S. Watkins, M.N. Jato, A. van der Straten, and L.-P.M. Tsitsol
1997 Social network associations with contraceptive use among Cameroonian women in voluntary associations. *Social Science and Medicine* 45(5):677–687.
van de Kaa, D.J.
1996 Anchored narratives: The story and findings of half a century of research into the determinants of fertility. *Population Studies* 50:389–432.
van de Walle, E., and E. P. Renne, eds.
2001 *Regulating Menstruation.* Chicago: University of Chicago Press.
Voloshinov, V.N.
1986 *Marxism and the Philosophy of Language.* Translated by L. Metejka and I.R. Titunik. Cambridge, MA: Harvard University Press.
Watkins, S., and D. Hodgson
1998 From mercantilists to neo-Malthusians: The international population movement and the transformation of population ideology in Kenya. Unpublished paper prepared for discussion at the National Academy of Sciences Workshop on Social Dynamics of Fertility Change in Developing Countries, January 29–30, Washington, DC.
Watkins, S.C.
1991 *From Provinces into Nations: The Demographic Integration of Western Europe, 1870–1960.* Princeton: Princeton University Press.
Wertsch, J.V., and M. Hickman
1987 Problem solving in social interaction: A microgenetic analysis. In *Social and Functional Approaches to Language and Thought,* M. Hickman, ed. Orlando, FL: Academic Press.
Wittgenstein, L.
1958 *Philosophical Investigations.* Oxford: Blackwell.
Wolf, M.
1972 *Women and the Family in Rural Taiwan.* Stanford: Stanford University Press.
Wyon, J.B., and J.E. Gordon
1977 *The Khanna Study.* Cambridge, MA: Harvard University Press.
Zhao, Z.
1997 Deliberate birth control in China before 1970. *Population and Development Review* 23(4):729–767.

6

Learning and Using New Ideas: A Sociocognitive Perspective

KATHLEEN M. CARLEY

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 soaking 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, such as other individuals, organizations, books, 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; examples include economic, advice, friendship, or social support. Again most empirical studies focus 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

Kathleen Carley is professor of sociology at Carnegie Mellon University.

affects behavior such as their ability to acquire and communicate information. At the tie level, structural constraints on the pattern of relations affect 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 commonplace 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 et al., 1977; Kahneman et al., 1982). Research following 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 in making decisions, individuals do not have full information and do not use all of the information 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. Because 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.

A wide range of findings exists 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 (Fiske and Taylor, 1991). 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 because of 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, such as ACT-R and Soar (for a more detailed review, see National Research Council, 1998). 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 et al., 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 affecting individuals' 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, 1971; Hunter et al., 1984; for a more complete review, see National Research Council, 1998). This work often focuses on how attributes of the message, message content, and the sender affect 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 the following (Whittaker, 1967, and 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 sociocognitive process. The likelihood of the diffusing information affecting behavior is a function of whether those others one comes into 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 (Tverksy 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 et al., 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 overestimate the degree to which their own past behavior, as well as their expected future behavior, is truly diagnostic of other individuals' 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" (Tversky and Kahneman, 1974:1127). 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 the strongest contributors, if not the strongest. This possible overrating of self is seen as related to a need by 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 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 (Fischoff et al., 1981; MacCrimmon and Wehrung, 1986). Fischoff et al. (1981) 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 (Thoits, 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 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, to be really effective the information provider 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 et al., 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). Group think 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, this means that learning new information in a group setting can cause the individuals to misestimate its importance and either overattend or underattend to the new information. Recent work in this area suggests that these group behaviors may be a function of both the initial distribu-

tion of information, beliefs, attitudes, and decisions as well as the underlying network connecting group members (Friedkin and Johnsen, 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 et al., 1991; Moreland, in press). Related ideas are joint remembering (Edwards and Middleton, 1986) and group remembering. 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 et al. (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 et al., 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 his or her position in the underlying social network. This point is eloquently made by the decades of research on social structure that has repeatedly demonstrated that an individual's beliefs, attitudes, knowledge, and actions are 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; Wellman, 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 a large number of other individuals) 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 on novel information or to generate innovations (Burt, 1973, 1980; Lin and Burt, 1975). Individuals who are more central may be overconstrained and so unable to act on novel information, particularly if they are embedded in a large number of triadic (Simelian) relations (Krackhardt, 1999a, 1999b). 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 influence 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 et al., 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 et al., 1948; Allen, 1977; Cole and Cole, 1973; Valente, 1995). Researchers have examined the diffusion of many different types of information, including rumors (Festinger et al., 1948, Festinger et al., 1950), job openings (Granovetter, 1974), scientific information (Price, 1965a, 1965b; Carley, 1990), technological information (Allen, 1977), and information about family planning (Valente et al., 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 thus 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). 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 his or her 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 his or her social network and the opinions held by those in that network collectively influence the individual's opinion (Friedkin and Johnsen, 1990).

Recent work on contraceptive use demonstrates the myriad of ways in which the underlying social network affects choice (Entwisle 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, although 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, 1969; Roethlisberger and Dickson, 1939). This is referred to as multiplexity (White et al., 1976). Ties include socioemotional ties such as friendship, and 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). Such ties have both a direct effect on the individual's information-gathering ability (changing what information is accessible) and an indirect effect by influencing the degree of social support, which influences the individual's mental health and affective state. This 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 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, nonsymmetric 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. Because of 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, 1974). Motivation then affects the way in which the channels are used, but not whether the social structure bears a relation on diffusion. A type of variant on the information-seeking models is the utility maximization model. 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 et al., 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 homogeneous (that is, most people in an individual's network are, for example, of the same gender, race, or educational level). Further, as networks of friends evolve, the overall network of individuals becomes organized into a set of self-reinforcing groups (Zeggelink et al., 1996; Stokman and Zeggelink, 1996). Individuals who are under stress tend to drop from their social network 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 et al. (1986), in discussing a local news event, noted that 80 percent 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 media, and indeed any communication media that encapsulate the views of the author, increase the author's reach and so make possible the wider and more rapid spread of information (Kaufer and Carley, 1993, 1994, 1996). The mass media often become the primary source of details on new information because of their one-to-many capabilities and 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 et al., 1995).

Communication technologies are not guaranteed to increase the extent to which individuals are informed. Telecommunication technologies often have 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, 1995, 1996). Changing access to technology can alter the underlying network structure and so alter who is likely to have access to what information (Alstyne and Brynjolfsson, 1996; Carley, 1995, 1996) and thus change the distribution of power (Barley, 1990; Butler and Gibbons, 1997).

Perhaps the most important feature of the new telecommunication 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 e-mail can reduce social status cues and increase anonymity, thus facilitating the acquisition of novel and "stressful" information (Sproull and Kiesler, 1991). Communication technologies that 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 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 also 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 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 et al., 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 multiagent models using spatial positioning now can be used to develop veridical theories of the impact of location on information diffusion and choice. Further, the new Geographic Information 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 rather perceived distance. In particular, low-cost telecommunication options are providing individuals with the opportunity to create physically distant socioemotional 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 empirical studies demonstrate that social pressure influences individuals' attitudes. In particular, an individual's attitude is influenced by what he or she thinks others believe and social norms (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 Johnsen, 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, 1999). New models of individuals' perceptions of fertility and the risk of conception are needed that offer a social learning perspective that accounts for differences (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 versus structural influences by varying parameters of social influence (near versus distal others, relational versus 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 individuals' personal characteristics influence the likelihood that they will discover new information (Allen, 1977). 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 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 sociocultural environment changes. Subgroups (Carley, 1991) and subcultures form (Latane and Bourgeois, 1996). Certain beliefs come to dominate (Krackhardt, 1997; Boorman and Levitt, 1980). Three basic approaches are being examined: spatial basis, cultural connections, and sociobiological 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). 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 that influence who interacts with whom can give rise to locally consistent patterns of shared attitudes, meanings, and beliefs. An example of this approach is Latane's dynamic social impact theory (DSIT), which 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 of 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 constructural theory (Carley, 1990, 1991, 1995; Kaufer and Carley, 1993). Constructural theory posits that both the individual cognition and the sociocultural environment are continuously constructed and reconstructed as individuals concurrently go through a cycle of interaction, adaptation, and motivation that 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 lead to the coevolution of social structure and culture. Concurrent actions lead to the redistribution of information and interaction partners across the actors (Carley, 1999). The innovator's position in the sociocultural environment determines how fast new ideas diffuse, consensus forms, and cliques form. However, as ideas diffuse, consensus forms, and cliques evolve, the innovator's position changes. A consequence is that very minute initial differences in the underlying sociocultural configurations may facilitate or hinder information diffusion and consensus formation. Communication technologies affect which sociocultural 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, 2001).

According to the constructural perspective, beliefs and attitudes mediate one's interpersonal relationships through a process of "social ad-

justment" (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 extent of the underlying information. Consequently, large information-poor groups can become dominated by erroneous beliefs. For example, in an 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. Because the perceptions of mortality declines are related to fertility declines (Montgomery and Casterline, 1998), an underlying constructural process that 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 sociobiology 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 individuals hold 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 preinnovation state to recover dominance in the organization, even if it begins with the same structural conditions that the innovators enjoyed.

TOWARD A SOCIOCOGNITIVE 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 he or she receives 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 coevolves.

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 individuals' networks 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, location, and choice. This defines a set of networks (see Table 6-1). What this summary has indicated is that each of these networks plays a role in affecting fertility-related behavior. Most studies, however, have considered only a couple of cells in the metamatrix at a time, and kept the others fixed. For example, Montgomery and Casterline (1998) model diffusion

TABLE 6-1 Metamatrix 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

and choice (thus the knowledge network and choice network) by keeping the social network fixed and ignoring all other networks.

The diffusion models that have been used in social and organizational studies have two key advantages over those currently used in fertility studies. First, in some of these models the social network and knowledge network coevolve; neither is taken as fixed. This enables the long-run consequence of policy interventions to be evaluated more completely. Second, in these models the agents are heterogeneous; that is, 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, multiagent models that capture this heterogeneity may afford better predictions and more accurate estimates of the impact of policies.

Multiagent 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.

REFERENCES

Abler, R., J.S. Adams, and R.F.P. Gould
1971 *Spatial Organization*. Englewood Cliffs, NJ: Prentice-Hall.

Ajzen, I., and M. Fishbein
1980 *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Prentice-Hall.

Allen, T.J.
1977 *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R and D Organization*. Cambridge, MA: MIT Press.

Alloy, L.B., ed.
1988 *Cognitive Processes in Depression*. New York: Guilford Press.

Alstyne, M.v., and E. Brynjolfsson
1995 Communication Networks and the Rise of an Information Elite—Does Communication Help the Rich Get Richer? Unpublished paper presented at the International Conference on Information Systems, December 14–17, Amsterdam.
1996 Wider access and narrower focus: Could the Internet Balkanize science? *Science* 274(5292):1479–1480.

Anderson, N.H.
1959 Test of a model for opinion change. *Journal of Abnormal and Social Psychology* 59:371–381.
1971 Integration theory and attitude change. *Psychological Review* 78:171–206.

Anderson, N.H., and C. Hovland
1957 The representation of order effects in communication research. In *The Order of Presentation in Persuasion*, C. Hovland, ed. New Haven: Yale University Press.

Bandura, A.
1977 *Social Learning Theory*. Englewood Cliffs, NJ: Prentice-Hall.

Banks, D., and K.M. Carley
1996 Models of social network evolution. *Journal of Mathematical Sociology* 21(1-2):173–196.

Barley, S.
1990 The alignment of technology and structure through roles and networks. *Administrative Science Quarterly* 61–101.

Behrens, D.M.
1997 Self-Isolation and The Structuring of Support: The Relationship Between Stress and Network Evolution. Unpublished Ph.D. dissertation, Carnegie Mellon University.

Bell, D.E.
1982 Regret in decision making under uncertainty. *Operations Research* 30:961–981.

Boorman, S.A., and P.R. Levitt
1980 *The Genetics of Altruism*. New York: Academic Press.

Branscomb, A.W.
1994 *Who Owns Information? From Privacy to Public Access*. New York: Basic Books.

Burt, R.S.
1973 The differential impact of social integration on participation in the diffusion of innovations. *Social Science Research* 2:125–144.
1980 Innovation as a structural interest: Rethinking the impact of network position innovation adoption. *Social Networks* 4:337–355.
1982 *Toward a Structural Theory of Action*. New York: Academic Press.

Butler, B.S., and D.E. Gibbons
1997 Power distribution as a catalyst and consequence of decentralized technology diffusion. In *Information Systems and Technology: Innovation and Diffusion*, T. Larsen and G. McGuire, eds. Hershey, PA: Idea Group.

Cannon-Bowers, J.A., and E. Salas
1990 Cognitive Psychology and Team Training: Shared Mental Models in Complex Systems. Unpublished paper presented at the annual meeting of the Society for Industrial and Organizational Psychology, Miami, FL.

Cantril, H.
1946 The intensity of an attitude. *Journal of Abnormal and Social Psychology* 41:129–135.

Carley, K.M.
1986 An approach for relating social structure to cognitive structure. *Journal of Mathematical Sociology* 12(2):137–189.
1990 Structural constraints on communication: The diffusion of the homomorphic signal analysis technique through scientific fields. *Journal of Mathematical Sociology* 15(3-4):207–246.
1991 A theory of group stability. *American Sociological Review* 56(3):331–354.
1995 Communication technologies and their effect on cultural homogeneity, consensus, and the diffusion of new ideas. *Sociological Perspectives* 38(4):547–571.
1996 Communicating new ideas: The potential impact of information and telecommunication technology. *Technology in Society* 18(2):219–230.
1999 On the evolution of social and organizational networks. Pp. 3–30 in Vol. 16 (special issue), Research in the Sociology of Organizations in *Networks In and Around Organizations*, Steven B. Andrews and David Knoke, eds. Stamford, CT: JAI Press, Inc.

Carley, K.M., and V. Hill
2001 Structural change and learning within organizations. In *Dynamics of Organizational Societies: Models, Theories and Methods*, Alessandro Lomi, ed. Cambridge, MA: MIT Press/AAAI Press/Live Oak.

Carley, K.M., and D. Krackhardt
1996 Cognitive inconsistencies and non-symmetric friendship. *Social Networks* 18:1–27.
Carley, K.M., and A. Newell
1994 The nature of the social agent. *Journal of Mathematical Sociology* 19(4):221–262.
Carley, K.M., and M.J. Prietula
1994 ACTS Theory: Extending the model of bounded rationality. Pp. 55–88 in *Computational Organization Theory*, K.M. Carley and M.J. Prietula, eds. Hillsdale, NJ: Lawrence Erlbaum Associates.
Carley, K.M., and D.M. Svoboda
1996 Modeling organizational adaptation as a simulated annealing process. *Sociological Methods and Research* 25(1):138–168.
Carley, K.M., with K. Wendt
1991 Electronic mail and scientific communication: A study of the soar extended research group. *Knowledge: Creation, Diffusion, Utilization* 12(4):406–440.
Chapman, L.J., and J.P. Chapman
1967 Genesis of popular but erroneous psychodiagnostic observations. *Journal of Abnormal Psychology* 72(3):193–204.
1969 Illusory correlation as an obstacle to the use of valid psychodiagnostic signs. *Journal of Abnormal Psychology* 74(3): 271–280.
Cole, J.R., and S. Cole
1973 *Social Stratification in Science*. Chicago: University of Chicago Press.
Coleman, J.S., E. Katz, and H. Menzel
1966 *Medical Innovation: A Diffusion Study*. New York: Bobbs-Merrill Company, Inc.
Connolly, T.
1993 Why classical decision theory is an inappropriate standard for evaluating and aiding most human decision making. Chap. 2 in *Decision Making in Action: Models and Methods*, Gary A. Klein, ed. Norwood, NJ: Ablex.
Cooley, C.
1902 *Human Nature and Social Order*. New York: Scribner.
Cyert, R., and J.G. March
1956 Organizational factors in the theory of oligopoly. *Quarterly Journal of Economics* 70:44–64.
1963 *A Behavioral Theory of the Firm*. Englewood Cliffs, NJ: Prentice-Hall.
Danes, J.E., J.E. Hunter, and J. Woelfel
1984 Belief change and accumulated information. In *Mathematical Models of Attitude Change: Change in Single Attitudes and Cognitive Structure*, J. Hunter, J. Danes, and S. Cohen, eds. Orlando, FL: Academic Press.
Dawes, R.M.
1989 Statistical criteria for establishing a truly false consensus effect. *Journal of Experimental Social Psychology* 25:1–17.
1990 The potential non-falsity of the false consensus effect. Pp. 179–199 in *Insights in Decision Making: A Tribute to Hillel J. Einhorn*, R.M. Hogarth, ed. Chicago: University of Chicago Press.
Dawes, R.M., and M. Mulford
1996 The false consensus effect and overconfidence: Flaws in judgment or flaws in how we study judgment? *Organizational Behavior and Human Decision Processes* 65(3):201–211.
Doreian, P., and F.N. Stokman, eds.
1997 *Evolution of Social Networks*. Amsterdam: Gordon and Breach Publishers.
Durlauf, S.N.
1996 Statistical Mechanics Approaches to Socioeconomic Behavior. Working Paper, Santa Fe Institute, Santa Fe, NM.

Entwisle, B., R.R. Rindfuss, D. Guilkey, A. Chamratrithirong, S.R. Curran, and Y. Sawangdee
1996 Community and contraceptive choice in rural Thailand: A case study of Nan Rong. *Demography* 33(1):1–11.
Entwisle, B., and J. Godley
1998 Village Networks and Patterns of Contraceptive Choice. Unpublished paper presented at the Workshop on The Social Processes on Underlying Fertility Change in Developing Countries, January 29–30, Washington, DC.
Epstein, J., and R. Axtell
1996 *Growing Artificial Societies*. Boston: MIT Press.
Fauconnier, G.
1985 *Mental Spaces: Aspects of Meaning Construction in Natural Language*. Cambridge, MA: MIT Press.
Feldman, M.S., and J.G. March
1981 Information in organizations as signal and symbol. *Administrative Science Quarterly* 26:171–186.
Festinger, L.
1954 A theory of social comparison processes. *Human Relations* 7:114–140.
1957 *A Theory of Cognitive Dissonance*. Evanston, IL: Row Peterson.
Festinger, L., D. Cartwright, K. Barber, J. Fleishl, J. Gottdanker, A. Keysen, and G. Leavitt
1948 The study of a rumor: Its origin and spread. *Human Relations* 1:464–486.
Festinger, L., S. Schachter, and K. Back
1950 *Social pressures in informal groups: A study of human factors in housing*. Palo Alto, CA: Stanford University Press.
Fischoff, B., S. Lichtenstein, P. Slovic, S. Derby, and R. Keeney
1981 *Acceptable Risk*. New York: Cambridge University Press.
Fishbein, M., and I. Ajzen
1975 *Belief, Attitude, Intention and Behavior*. Reading, MA: Addison-Wesley.
Fiske, S., and S. Taylor
1991 *Social Cognition*. New York: McGraw-Hill.
Freeman, L.C.
1979 Centrality in social networks: Conceptual clarification. *Social Networks* 1:215–239.
Friedkin, N.E.
1991 Theoretical foundations for centrality measures. *American Journal of Sociology* 96(6): 1478–1504.
1993 Structural bases on interpersonal influence in groups: A longitudinal case study. *American Sociological Review* 56(6):861–872.
Friedkin, N.E., and E.C. Johnsen
1990 Social influence and opinions. *Journal of Mathematical Sociology* 15:193–205.
Fulk, J.
1993 Social construction of communication technology. *Academy of Management Journal* 36(5):921–950.
Gantz, W., K.A. Krendl, and S.R. Robertson
1986 Diffusion of a proximate news event. *Journalism Quarterly* 63(2):282–287.
Granovetter, M.S.
1973 The strength of weak ties. *American Journal of Sociology* 78(6):1360–1380.
1974 *Getting a Job: A Study of Contacts and Careers*. Cambridge, MA: Harvard University Press.
Hanson, P.P., ed.
1990 *Information, Language, and Cognition*. Vancouver: University of British Columbia Press.
Haythornthwaite, C., B. Wellman, and M. Mantei
1995 Work relationships and media use: A social network analysis. *Group Decision and Negotiation* 4:193–211.

Heider, F.
1946 Attitudes and cognitive organization. *Journal of Psychology* 21:107–112.
Heider, F.
1958 *The Psychology of Interpersonal Relations*. New York: Wiley.
Heise, D.R.
1979 *Understanding Events: Affect and the Construction of Social Action*. Cambridge, Eng.: Cambridge University Press.
Heise, D.R., and N.J. McKinnon
1987 Affective bases of likelihood judgments. *Journal of Mathematical Sociology* 13:133–151.
Herek, G.
1987 Can functions be measured? A new perspective on the functional approach to attitudes. *Social Psychology Quarterly* 50:285–303.
Hiltz, S.R., and B. Wellman
1997 Asynchronous learning networks as a virtual classroom. *Communications of the ACM* 40(9):44–49.
Holland, P.W., and S. Leinhardt
1977 A dynamic model for social networks. *Journal of Mathematical Sociology* 3:85–111.
Hovland, C.
1972 Reconciling conflicting results derived from experimental and survey studies of attitude change. In *The Handbook of Social Psychology*, G. Lindzey, ed. Reading, MA: Addison-Wesley.
Hovland, C., and H. Pritzker
1957 Extent of opinion change as a function of amount of change advocated. *Journal of Abnormal and Social Psychology* 54:257–261.
Huguet, P., and B. Latane
1996 Social representations as dynamic social impact. *Journal of Communication* 46(4):57–63.
Humphrey, R.H., P.M. O'Malley, L.D. Johnston, and J.G. Bachman
1988 Bases of power, facilitation effects, and attitudes and behavior: Direct, indirect, and interactive determinants of drug use. *Social Psychology Quarterly* 51:329–345.
Hunter, J.E., J.E. Danes, and S.H. Cohen
1984 *Mathematical Models of Attitude Change*. New York: Academic Press.
Hutchins, E.
1995 *Cognition in the Wild*. Cambridge, MA: MIT Press.
Hutchins, E., and B. Hazlehurst
1991 Learning in the cultural process. In *Artificial Life II*, C. Langton, C. Taylor, J.D. Farmer, and S. Rasmussen, eds. Reading, MA: Addison-Wesley.
Innami, I.
1992 Determinants of the quality of group decisions and the effect of consensual conflict resolution. *Academy of Management Best Papers Proceedings* 217–221.
Insko, C.
1967 *Theories of Attitude Change*. New York: Appleton-Century-Crofts.
Janis, I.
1982 *Groupthink*. 2d ed. Boston: Houghton Mifflin Company.
Johnson, E.C.
1985 Structure and process: Agreement models for friendship formation. *Social Networks* 8:257–306.
Kahneman, D., P. Slovic, and A. Tversky
1982 *Judgment Under Uncertainty: Heuristics and Biases*. London: Cambridge University Press.

Kahneman, D., and A. Tversky
1979 Prospect theory: An analysis of decision under risk. *Econometrica* 47:263–291.
Katz, D.
1960 The functional approach to the study of attitudes. *Public Opinion Quarterly* 24:163–204.
Katz, E.
1961 The social itinerary of technical change: Two studies on the diffusion of innovation. In *Studies of Innovation and of Communication to the Public*, W. Schramm, ed. Stanford: Stanford University, Institute for Communication Research.
Kaufer, D.S., and K.M. Carley
1993 *Communication at a Distance: The Effect of Print on Socio-Cultural Organization and Change*. Hillsdale, NJ: Lawrence Erlbaum Associates.
1994 Some concepts and axioms about communication: Proximate and at a distance. *Written Communication* 11(1):8–42.
1996 The influence of print on social and cultural change. *Annual Review of Applied Linguistics* 16:14–25.
Kelley, H.H.
1967 Attribution theory in social psychology. In *Nebraska Symposium on Motivation*, D.L. Vine, ed. Lincoln: University of Nebraska Press.
Kernis, M.H.
1984 Need for uniqueness, self-schemas, and thought as moderators of the false–consensus effect. *Journal of Experimental Social Psychology* 20:350–362.
Klein, G.A., ed.
1993 *Decision Making in Action: Models and Methods*. Norwood, NJ: Ablex.
Krackhardt, D.
1997 Organizational viscosity and the diffusion of controversial innovations. *Journal of Mathematical Sociology* 22:177–199.
1999a The ties that torture: Simmelian tie analysis of organizations. *Research in the Sociology of Organizations* 16:183–210.
1999b Simmelian tie: Super strong and sticky. Pp. 21–38 in *Power and Influence in Organizations*, Roderick Kramer and Margaret Neale, eds. Thousand Oaks, CA: Sage.
Kraut, R., R.E. Rice, C. Cool, and R. Fish
1997 Varieties of social influence: The role of utility and norms in the success of a new communication medium. *Organization Science* 9(4):437–453.
Latane, B.
1996 Dynamic social impact: The creation of culture by communication. *Journal of Communication* 46(4):13–25.
Latane, B., and M.J. Bourgeois
1996 Experimental evidence for dynamic social impact: The emergence of subcultures in electronic groups. *Journal of Communication* 46(4):35–47.
Latane, B., J.H. Liu, A. Nowak, M. Bonevento, and Zheng Long
1995 Distance matters: Physical space and social impact. *Personality and Social Psychology Bulletin* 21(8):795–805.
Leenders, R.T.A.J.
1997 Longitudinal behavior of network structure and actor attributes: Modeling interdependence of contagion and selection. Pp. 165–184 in *Evolution of Social Networks*, Patrick Doreian and Frans N. Stokman, eds. Amsterdam: Gordon and Breach.
Liang, D.W., R. Moreland, and L. Argote
1995 Group versus individual training and group performance: The mediating role of transactive memory. *Personality and Social Psychology Bulletin* 21(4):384–393.

Lin, N., and R.S. Burt
1975 Differential effects of information channels in the process of innovation diffusion. *Social Forces* 54:256–274.
Loomes, G., and R. Sugden
1982 Regret theory: An alternative theory of rational choice under uncertainty. *Economic Journal* 92:805–824.
MacCrimmon, K.R., and D.A. Wehrung
1986 *Taking Risks: The Management of Uncertainty*. New York: Free Press.
Marks, G.
1984 Thinking one's abilities are unique and one's opinions are common. *Personality and Social Psychology Bulletin* 10:203–208.
Mead, G.H.
1962 *Mind, Self, and Society*. Chicago: University of Chicago Press.
Miller, S.M.
1995 Monitoring versus blunting styles of coping with cancer influence the information patients want and need about their disease: Implications for cancer screening and management. *Cancer* 76(1):177–197.
Mita, R., and R. Simmons
1995 Diffusion of the culture of contraception: Program effects on young women in rural Bangladesh. *Studies in Family Planning* 26(1):1–13.
Molm, L.D.
1978 Sex–role attitudes and the employment of married women: The direction of causality. *Sociological Quarterly* 19:522–533.
Montgomery, M.R.
1997 Learning and lags in mortality perceptions. Pp. 112–127 in *From Death to Birth: Mortality Decline and Reproductive Change*, Barney Cohen and Mark Montgomery, eds. Committee on Population, Commission on Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.
1999 Mortality Decline and the Demographic Response: Toward a New Agenda. PRD Working Paper 122, Population Council.
Montgomery, M.R., and J.B. Casterline
1996 Social learning, social influence, and new models of fertility. *Population and Development Review* (Supplement) 22:151–175.
1998 Social Networks and the Diffusion of Fertility Control. PRD Working Paper 119, Population Council.
Moreland, R.L.
in press Transactive memory in work groups and organizations. In *Shared Knowledge in Organizations*, L. Thompson, D. Messick, and J. Levine, eds. Mahwah, NJ: Lawrence Erlbaum Associates.
Moreland, R.L., L. Argote, and R. Krishnan
1996 Socially shared cognition at work: Transactive memory and group performance. Pp. 57–84 in *What's Social About Social Cognition? Research on Socially Shared Cognition in Small Groups*, J.L. Nye and A.M. Brower, eds. Newbury Park, CA: Sage Publications.
in press Training people to work in groups. In *Applications of Theory and Research on Groups to Social Issues*, R.S. Tindale, J. Edwards, and E.J. Posvac, eds. New York: Plenum Press.
Morris, M.
1994 Epidemiology and social networks: Modeling structured diffusion. Pp. 26–52 in *Advances in Social Network Analysis*, S. Wasserman and J. Galskiewicz, eds. Thousand Oaks, CA: Sage.

National Research Council
1998 *Modeling Human and Organizational Behavior: Application to Military Simulations*. Panel on Modeling Human Behavior and Command Decision Making: Representations for Military Simulations. Richard W. Pew and Anne S. Mavor, eds. Commission on Behavioral and Social Sciences and Education. Washington, DC: National Academy Press.
Orbell, J.M., and R.M. Dawes
1993 Social welfare, cooperators' advantage, and the option of not playing the game. *The American Sociological Review* 58(6):787–800.
Orbell, J.M., A.J.C. van de Kragt, and R.M. Dawes
1988 Explaining discussion-induced cooperation. *Journal of Personality and Social Psychology* 54(5):811–819.
Plous, S.
1993 *The Psychology of Judgment and Decision Making*. New York: McGraw-Hill.
Price, D.J.
1965a Networks of scientific papers. *Science* 149:510–515.
1965b Is technology independent of science? *Technology and Culture* 6:553–568.
Pruitt, D.
1971a Choice shifts in group discussion: An introductory review. *Journal of Personality and Social Psychology* 20:339–360.
1971b Conclusions: Toward an understanding of choice shifts in group discussion. *Journal of Personality and Social Psychology* 20:495–510.
Rapoport, A.
1953 Spread of information through a population with socio-structural bias: II. Various models of partial transitivity. *Bulletin of Mathematical Biophysics* 15:535–546.
Reitman, W.R.
1965 *Cognition and Thought; An Information-Processing Approach*. New York: Wiley.
Rice, R.E.
1984 *The New Media: Communication, Research, and Technology*. Beverly Hills, CA: Sage.
1993 Using network concepts to clarify sources and mechanisms of social influence. Pp. 43–52 in *Advances in Communication Network Analysis*, W. Richards, Jr., and G. Barnett, eds. Norwood, NJ: Ablex.
1994 Relating electronic mail use and network structure to R&D work networks and performance. *Journal of Management Information Systems* 11(1):9–20.
Rice, R.E., and C. Aydin
1991 Attitudes toward new organizational technology: Network proximity as a mechanism for social information processing. *Administrative Science Quarterly* 36(2):219–244.
Ridgeway, C.L., and L. Smith–Lovin
1996 Gender and social interaction. *Social Psychology Quarterly* 59(3):173–175.
Roethlisberger, F.J., and W.J. Dickson
1939 *Management and the Worker*. Cambridge, MA: Harvard University Press.
Rogers, E.M.
1995 *Diffusion of Innovations*. New York: Free Press.
Ross, L., T.M. Amabile, and J.L. Steinmetz
1977 Social roles, social controls, and biases in the social perception process. *Journal of Personality and Social Psychology* 35:485–494.
Salancik, G.R., and J. Pfeffer
1978 Social information processing approach to job attitudes and task design. *Administrative Science Quarterly* 23:224–253.

Salas, E., R.J. Stout, and J.A. Cannon-Bowers
1994 The role of shared mental models in developing shared situational awareness. Pp. 297–304 in *Situational Awareness in Complex Systems*, R.D. Gilson, D.J. Garland, and J.M. Koonce, eds. Daytona Beach, FL: Embry-Riddle Aeronautical University Press.
Sampson, S.
1969 Crisis in a cloister. Unpublished Ph.D. dissertation. Cornell University, Ithaca, NY.
Sanil, A., D. Banks, and K. Carley
1995 Models for evolving fixed node networks: Model fitting and model testing. *Social Networks* 17(1):65–81.
Simon, H.A.
1976 *Administrative Behavior*. 3d ed. New York: Free Press.
1979 Rational decision making in business organizations. *American Economic Review* 69(4):493–513.
Smith, M.
1973 Political Attitudes. In *Handbook of Political Psychology*, Jeanne Knutson, ed. San Francisco: Jossey-Bass.
Smith, M., J. Bruner, and R. White
1956 *Opinions and Personality*. New York: Wiley.
Smith-Lovin, L.
1987a Affect control theory: An assessment. *Journal of Mathematical Sociology* 13:171–192.
1987b The affective control of events within settings. *Journal of Mathematical Sociology* 13:71–101.
Sproull, L., and S. Kiesler
1991 *Connections: New Ways of Working in the Networked Organization*. Cambridge, MA: MIT Press.
Stokman, F.N., and E.P.H. Zeggelink
1996 "Self-organizing" friendship networks. Pp. 385–418 in *Frontiers in Social Dilemmas Research*, W.B.G. Liebrand and D.M. Messick, eds. Berlin: Springer Verlag.
Strang, D., and J.W. Meyer
1993 Institutional conditions for diffusion. *Theory and Society* 22:487–512.
Strang, D., and N. Tuma
1993 Spatial and temporal heterogeneity in diffusion. *American Journal of Sociology* 99:614–639.
Thoits, P.A.
1991 Patterns in coping with controllable and uncontrollable events. Pp. 235–258 in *Life-span Developmental Psychology: Perspectives on Stress and Coping*, E.M. Cummings, A.L. Greene, and K.H. Karraker, eds. Hillsdale, NJ: Lawrence Erlbaum Associates.
Tversky, A., and D. Kahneman
1974 Judgment under uncertainty: Heuristics and biases. *Science* 185:1124–1131.
1981 The framing of decisions and the psychology of choice. *Science* 211:453–458.
Valente, T.W.
1995 *Network Models of the Diffusion of Innovations*. Cresskill, NJ: Hampton Press.
1996 Social network thresholds in the diffusion of innovations. *Social Networks* 18:69–89.
Valente, T.W., Y.M. Kim, C. Lettenmaier, W. Glass, and Y. Dibba
1994 Radio and the promotion of family planning in The Gambia. *International Family Perspectives Planning* 20(3):96–100.

Valente, T.W., S. Watkins, M.N. Jato, A. Van der Straten, and L.M. Tsitsol
1997 Social network associations with contraceptive use among Cameroonian women in voluntary associations. *Social Science and Medicine* 45:677–687.
Walsh, J.P., and L. Fahey
1986 The role of negotiated belief structures in strategy making. *Journal of Management* 12:325–338.
Wasserman, D., R.O. Lempert, and R. Hastie
1991 Hindsight and causality. *Personality and Social Psychology Bulletin* 17(1):30–35.
Weenig, M.W., and C.J. Midden
1991 Communication network influences on information diffusion and persuasion. *Journal of Personality and Social Psychology* 61(5):734–742.
Weesie, J., and H. Flap, eds.
1990 *Social Networks Through Time*. Belgium: ISOR/University of Utrecht.
Wegner, D.M.
1987 Transactive memory: A contemporary analysis of the group mind. Pp. 185–208 in *Theories of Group Behavior*, B. Mullen and G.R. Goethals, eds. New York: Springer-Verlag.
1995 A computer network model of human transactive memory. *Social Cognition* 13(3): 319–339.
Wegner, D.M., R. Erber, and P. Raymond
1991 Transactive memory in close relationships. *Journal of Personality and Social Psychology* 61:923–929.
Wellman, B.
1992 Which ties provide what kinds of support? *Advances in Group Processes* 9:207–235.
1997 An electronic group is virtually a social network. Pp. 179–203 in *Culture of the Internet*, Sara Kiesler, ed. Mahwah, NJ: Lawrence Erlbaum Associates.
Wellman, B., and S.D. Berkowitz
1988 *Social Structures: A Network Approach*. Cambridge, Eng.: Cambridge University Press.
Wellman, B., and S. Wortley
1990 Different strokes from different folks: Community ties and social support. *American Journal of Sociology* 96(November):558–588.
White, H.C., S.A. Boorman, and R.L. Breiger
1976 Social structure from multiple networks. I. Blockmodels of roles and positions. *American Journal of Sociology* 81:730–780.
Whittaker, J.
1967 Resolution and the communication discrepancy issue in attitude change. In *Attitude Ego–Involvement and Change*, C. Sherif and M. Sherif, eds. New York: Wiley.
Zeggelink, E.P.H.
1993 *Strangers Into Friends: The Evolution of Friendship Networks Using an Individual Oriented Modeling Approach*. Amsterdam: Thesis Publishers.
1995 Evolving friendship networks: An individual oriented approach implementing similarity. *Social Networks* 17:83–110.
1996 "Self-organizing" networks of affective relations. Pp. 899–903 in *Third European Congress on Systems Science*, E. Pessa and M.P. Penna, eds. Rome: Edizione Kappa.
Zeggelink, E.P.H., F.N. Stokman, and G.G. van de Bunt
1996 The emergence of groups in the evolution of friendship networks. *Journal of Mathematical Sociology* 21:29–55. Also in *Evolution of Social Networks*, P. Doreian and F.N. Stokman, eds. Amsterdam: Gordon and Breach.