

# CHAPTER 6

## COMMUNICATION AND HUMAN FACTORS

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### 1 INTRODUCTION

Human factors is the study of the interaction of humans with systems, products, and the environment. Human factors research is traditionally found at the intersection of engineering, computer science, management, and psychology. In recent years communication scholars have joined in the interdisciplinary study of human factors design, particularly in the aviation and knowledge management industries (e.g., Eiff and Mattson, 1998; Mattson et al., 2001; Armentrout-Brazee and Mattson, 2004). This relatively new and evolving partnership is not surprising. As a science of human performance concerned with the physical, cognitive, and social abilities and limitations of people and a user-focused engineering discipline concerned with the design of interdependent systems for efficiency, safety, and quality (Salvendy, 1997), human factors involves communication within and among participants and technologies as a necessary yet complex condition for

effectiveness. Indeed, a Google search in August 2004, using the terms *communication* (or *communications*) and *human factors*, returned over 400,000 Web pages.

In general, communication processes are fundamental to what is designed (hardware and software), how it is designed (the relations among designers and stakeholders, typically conceived of as users), how it is used (the optimization of the interaction between the human and the physical component), and how the designed system influences subsequent communication among users of the system. A communication perspective goes beyond the psychological and physiological, to the social. Making sense of the intentions and suggestions of fellow designers, a system, its features, its uses, and its consequences requires social interaction and a heightened sensitivity to language and the ways in which communicative choices shape the perception and definition of situations.

As a scholarly field, communication has two distinct traditions: one rooted in rhetoric and the

humanities, and the other in systems theory and the social sciences. Since the earliest writings of Aristotle, rhetoricians have been concerned with means of persuasion, examining the efficacy of different types of logical, emotional, and ethical appeals, analyzing the credibility of message sources, and identifying the most effective language choices and communication strategies to influence people's attitudes and performance (Griffin, 1997). Since the 1930s, mass media scholarship, taking a behavioral science approach, has addressed the effects of mediated messages across varying communication technologies on a wide range of human activity and attitudes (e.g., Schramm, 1963; McLuhan, 1964). Many interpersonal, group, and organizational communication scholars, using linguistic, observational, survey, network, experimental, and ethnographic methods, focus on the multiple forms of message production, exchange, and interpretation and the pragmatic effects of interaction across a variety of social contexts (Griffin, 1997). Across traditions, many communication researchers focus on messages and their effects on interpretative processes, motivation, cognition, emotion, discrete and collaborative activities, decision making, and overall human performance.

The purpose of this chapter is to identify basic communication issues and processes that arise in pursuit of high-quality performance through the interaction of humans and technology. Communication, defined as the *collective, interactive process of generating and interpreting messages* (Stohl, 1995), focuses our attention on the networks of action and understanding that are created through coordinated activities and relationships. We are thus more concerned with the *relations between*, not the nature of nor the psychology of entities *within*, the interactive system. Although definitions and levels of analysis of the term *communication* can range from conversational interactions to global propaganda, and from dyadic interactions to mass organizing, we limit our discussion to concepts and examples of two or more people interacting (possibly by means of a mediating system) over time to create shared meaning through a common human verbal language. Figure 1 summarizes our area of focus. Note that a system (designed artifact) is considered from a communication perspective only as a possible medium for interaction among and between designers and users rather than from a traditional human factors emphasis on interaction with a system.

Within this constrained domain, the following sections introduce six main communication issues: messages, communication artifacts, communication characteristics of participants, group communication, communication networks, and communication environments. Working from the most basic unit of analysis, a message, to the most abstract, the communication environment, we identify analytic constructs and concepts that are fundamental for developing a communication perspective on human factors. The chapter ends with a brief application of these concepts to general stages of human factors activities in the design process.

## 2 MESSAGES

From a communication perspective on human factors, a *message* is the fundamental unit of interaction. The interface between humans or between human and machine is rooted in the exchange of messages, embedded in social interactions. Messages are simultaneously the cause and the explanation of many human performance problems. This fundamental dilemma can be seen in the various solutions to one of the most common problems: information overload. *Overload* refers to the transmission of new information at a rate that exceeds the input-processing and output-generating capabilities of individuals. Message overload may result in the intentional or unintentional modification of messages by omitting messages, modifying messages, and/or sampling messages. In each case the messages and patterns of message exchange are changed. The second type of response relates to network specialization. Relevant messages are redefined and delegated to others either in or outside the system, new priority systems are developed in which jobs are redefined in order to apply some selective criteria for message relevance or importance, and/or interpersonal networks are restructured so that there is decentralization and the creation of multiple channels. Each of these solutions makes it less likely that the individual will be saturated. In each of these solutions the interpersonal bonds between persons may be loosened, dissolved, or redefined, and new attachments will develop. In other words, it is impossible to separate relationships from message phenomena; there is no sharp dividing line between sender and receiver. Messages operate at multiple levels, assume multiple forms, and have multiple meanings and functions.

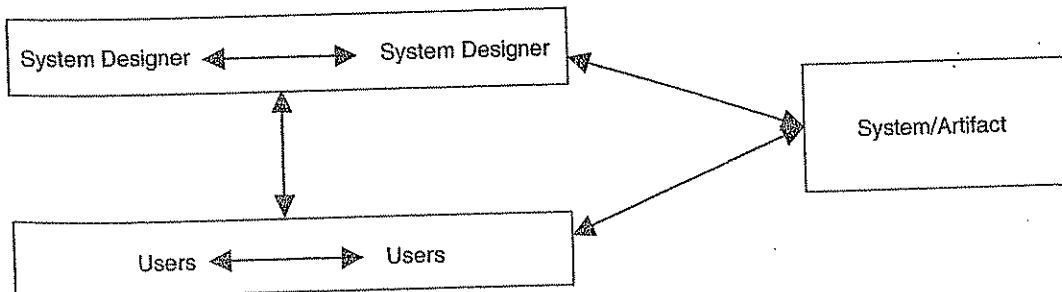


Figure 1 Communication relationships in the human factors emphasized in this chapter.

A message is not just the content or information as typically portrayed in *linear models of communication*. An illustration of these models is Shannon and Weaver's (1949) explication of information theory (designed to compute how much error can be reduced in a transmission given channel and coding constraints). In their model a *source* creates and then *encodes* a message, *transmits* it through a *channel*, and a *receiver decodes* the message, leading to a more informed state. Various forms of *noise* may occur through the system, and depending on its speed and extent, *feedback* may help verify or correct the message. Using this type of model of communication for human factors design focuses on maximizing the clarity of the messages through redundancy, message and channel modifications, and the elimination of environmental distractions. However, as useful as they may seem, transmission models that rely on a conduit metaphor of communication (Reddy, 1993) have several shortcomings that must be considered in the design of human factors.

## 2.1 What Communication Is Not

First, *communication is not linear*. There are two aspects of messages: ostensive messages, the *actual text* (this can be verbal, nonverbal, paralinguistic cues, or artifacts), and *internally experienced messages*, the interpretations of these ostensive messages (Stohl and Redding, 1987). Human factors analysts need to distinguish among the text, the representative intentions of the sender, and the interpretations of all interactants as they intersubjectively create meaning. For example, what constitutes "support" from a technical help desk is not straightforward. Considerable interaction between technical staff and a user department may be needed before there is shared agreement about the nature of a system problem, how to solve it, and even whether support has been provided.

Second, *communication is not passive*. There are no fixed roles of active sender and passive receiver. Message senders are simultaneously receivers; receivers are simultaneously senders. The message sent is not the message received. Communication requires active engagement on the part of all participants; it is a collaborative and oftentimes dialogic sense-making process in which meanings and interpretations are negotiated through hard work. Relational history, social context, and the medium may change the meaning and import of intended messages. Computer error messages such as "abort" or "kill job" may be seen as neutral computer commands, but clearly have additional potential meanings for users that may cause confusion, discomfort, or alienation.

Third, *communication is not unifunctional*. Every communication has a *content* and *relationship* aspect (Watzlawick et al., 1967). Messages not only convey information or content; they simultaneously communicate a relationship between communicants which describes how a message should be taken, thereby providing a context for interpretation. The relationship aspect is often called *metacommunication*, defined as

communication about the communication. Metacommunication helps interactants make sense of the message and may be associated with verbal, nonverbal, and/or paralinguistic cues. For example, when human factors engineers label the content of messages as *instructions*, they are providing specific information to participants *and* simultaneously telling the interactants that these messages are of a higher logical type; depending on the wording, the instructions may also convey relative status differentials between the technical expert and the novice user.

Fourth, *communication is not an uninterrupted series of interchanges*. *Punctuation* (not the punctuation of grammar and writing lessons) is the means by which participants organize interchanges and create causal maps (Watzlawick et al., 1967). Participants choose how they punctuate sequences, differentially attributing cause and effect, stimulus and response, and thus create meanings that may or may not be consistent with others in the system and with intended meanings. For example, from a designer's perspective, a series of messages in a training session may be viewed as a continuous sequence of exchanges in which one message is unambiguously the stimulus, the next is the user's response, and the third is the trainer's reinforcement. But from the perspective of the participants in the system, every message in the sequence can potentially and simultaneously be a stimulus, a response, and a reinforcement.

Fifth, *communication is not equivalent to reducing uncertainty*. Traditional approaches to communication view information as the opportunity to reduce uncertainty and lessen ambiguity in a given situation. For example, in information theory, messages contain bits of information that decrease entropy (randomness) and make things more predictable. The semantic aspects of communication are deemed irrelevant to the engineering aspects (Shannon and Weaver, 1949). *Uncertainty reduction theory* (Berger, 1986) also assumes that the main purpose of communication is to make sense of the world and that there is a universal human drive to reduce uncertainty. Behavioral mechanisms of uncertainty reduction are typically addressed through developing and following accepted procedural protocols, while cognitive uncertainty is reduced through information-seeking behaviors designed to acquire the necessary information. However, the reduction of uncertainty, the striving for message clarity, and the design of disambiguating activities cannot be assumed to be the underlying rationale for human activity nor the *raison d'être* for communication. Significant collaborative work related to identity management, task definition, role negotiation, and other types of interpretive processes are needed to create shared meanings that must be considered in any human factors design.

## 2.2 Ambiguity and Shared Meaning

Contemporary communication theorists have a complex view of human communication and uncertainty that has important implications for the study of human factors. First, lack of information does not necessarily motivate information seeking. Responses

to uncertainty are shaped by appraisals of the situation and emotional reactions to the context in which uncertainty arises (Brashers, 2001). Second, people tend to respond to uncertainty based on their assessments of the valence (positive or negative) and probability of an event happening (Babrow, 2001). In many situations, individuals may choose not to pursue more information, to reframe the issue, to ignore the uncertainty, or even to try to amplify the uncertainty. Thus, *uncertainty management* is a more useful way to consider the potential effects of ambiguity on human performance. Third, uncertainty reduction is not always an appropriate or desirable communication goal. For example, Eisenberg's (1984) work on *strategic ambiguity* reveals many ways in which messages may be designed ambiguously in order to promote unified diversity, preserve privileged positions, enable plausible deniability, and/or facilitate organizational change. Logos, organizational mission statements, and role definitions are often crafted in ways that are open to multiple interpretations and thereby can be defined by individuals within their own conceptual frameworks, enabling them to identify and find their own place within the system, yet simultaneously be considered universally defined across organizations or institutions. From this perspective, explicitly shared meaning is not the primary (or sufficient) goal of interaction; rather, it is organized action (Donnellon et al., 1986; Weick, 1995).

Stohl and Redding (1987) identify two other types of message ambiguity that have important implications for human factors design. Type 1 ambiguity occurs when a receiver is confused or uncertain about the meaning of a message. This may occur because the receiver cannot construct any plausible interpretation of the message (i.e., the message seems meaningless) or the receiver recognizes that there may be multiple possible meanings and cannot select or determine the intended meaning. When we have doubt as to what a message "means" we often seek out others in our network to help us interpret the message. Type 2 ambiguity occurs when there are two or more potential meanings to a message but the creator or receiver is unaware of this possibility. This type of ambiguity is perhaps most problematic for human factors design.

For example, in 1989, an Avianca jet crashed approaching John F. Kennedy Airport, killing 73 of the 158 people aboard. The jet, flying in stormy weather, had aborted a first landing approach and was preparing for another attempt when it crashed into a New York suburb northeast of the airport. The United Press International (UPI) report at the time of the crash highlighted the serious dangers of message type 2 ambiguity and pointed to the importance of shared meanings in safety procedures. "The investigation hinged on exactly what words the crew used to describe the low fuel situation to controllers, Lee Dickson, a member of the National Transportation Safety Board said. Dickson said recorded tapes of cockpit conversations revealed that crew members never used the word *emergency* but did say they needed *priority* when making their second landing

attempt after aborting the first." The UPI reported that when pilots declare a fuel emergency, the situation is considered very serious and the plane is given priority to land over all other waiting planes. The air traffic control manual has no listing under terminology for a "fuel priority" (Stohl, 1995, p. 58).

Several strategies exist for the development of shared meanings among diverse interactants. For example, a group of designers brought together for a new product or system development may lack shared understanding about the problem, norms, and behaviors of the members (Clark and Brennan, 1993). Proponents of distributed cognition suggest that shared understanding is created by the team sharing cognitive maps of factors and relationships at various levels of detail and by making tacit knowledge explicit and formalized (Nonaka and Takeuchi, 1995). Another approach is to create *shared artifacts* and *boundary objects* to achieve a collective understanding and the nature and goals of the task (Star, 1993; Suchman, 1995; Majchrzak et al., 2000). In his theory of how media and language are used to develop common ground, Clark (1996) calls these shared artifacts *external representations* or *coordination devices*. Such artifacts must lead to a unique solution and provide a rationale (through an identifiable purpose, individuals' ability to accomplish the purpose, and a mutual belief about the purpose and abilities) for participants to believe that they will converge on the same joint action. Similarly, Krauss and Fussell (1990) describe the communicative process by which descriptions of inanimate objects are transformed into referring expressions that are used in the development of common ground. On the first reference to an objective, people will use a long, rather unwieldy referring expression, but over the course of successive references will shorten the phrase to one or two words if reinforced by "back-channel" (e.g., "uh-uh," "umm," nods) responses that provide indications of what is understood. Olson and Olson (1997) extended this work to suggest that communication systems that foster the development of shared artifacts should have features that support linking conversations to these artifacts (such as allowing message revision and notifying others of relevant messages) and the creation and editing of these artifacts.

### 2.3 Feedback

Even most conduit models of communication, but certainly more interactive models, emphasize the important role of feedback for developing shared meaning, fostering learning, and repairing misunderstandings. If feedback or control is inaccurate, delayed, repressed, misinterpreted, or if the range through which organizational parameters can safely vary is too narrow, external variations can lead to deviation amplification and chaos (Mees, 1986). The communication processes and content fostering appropriate feedback are central to organizational and project functioning.

Research has shifted from considering feedback as something that a recipient receives passively to two forms of active feedback seeking: eliciting (direct)

and monitoring (indirect) (Fedor et al., 1992). These provide different forms of information and may be differentially appropriate. Eliciting gets only what others want to share. Monitoring acquires other information but requires making inferences about that information and its source from nonverbal cues and others' comments. Monitoring would seem more likely when the costs (perceived and actual) of asking directly are high, such as in public situations or low-trust climates. Also, feedback itself may generate uncertainty about its meaning, contingencies, and so on. So monitoring may precede eliciting, to determine costs and appropriateness of eliciting. In Fedor et al.'s (1992) study of 139 student helicopter pilots and 152 instructor pilots, the expected costs of seeking feedback and uncertainty from prior feedback were the most consistent predictors of eliciting and monitoring feedback. There was higher eliciting when the seeker had a high intolerance for ambiguity and the source had a low confrontational style; and higher monitoring under conditions of low self-esteem and low source credibility.

Although user feedback is often proposed as one way of resolving or preventing problems, there are at least two general classes of problems that make feedback much more problematic than presumed: (1) communication problems (such as ignoring information already available, changing usage contexts, and tensions among oppositional competence goals), and (2) organizational problems (such as uses and misuses of organizational memory, information systems designed to support "customer" feedback, the general level of technical ignorance, and overemphasis on rationalistic homeostasis).

The concepts of the two-level communication hierarchy—relational and content—may help explain some problematic feedback routines. "Behavior that may be normatively incompetent may be relationally competent, and vice versa" (Spitzberg, 1993, p. 153). For example, the valued norm of getting along with others (the relational meaning of an episode) may not always be an asset, because it may suppress conflict and resolution (the content meaning of an episode). If one's communication is goal-directed but people are faced with ambiguous, incompatible, or incompetent goals, dialectical motives arise (Argyris, 1986), such as politeness and assertiveness. Repressing conflicts and negatively valenced feedback (say, between a representative of a system design team and a potential user about the appropriate sequence of work processes) avoids impoliteness but potentially leads to relational dissatisfaction (client frustration, job alienation, turnover) or flawed systems.

Culnan (1989) makes the point that all transaction-processing systems are actually organizational message systems. That is, they both generate messages to the user (either a direct user or someone accessing information from the system) and to the organization that may or may not be recognized or intentional and may also foster, collect, and even analyze messages as feedback. Different transaction-processing systems

(structured, semistructured, or unstructured) may support or constrain different message processes: routing (selectively distributed, limiting overload); summarizing (reducing amount of message without loss of information); delays (intentional or not, beneficial or not); and modification (distortion, due to motivations or cognitive limitations) (Huber, 1982). For example, semistructured systems such as toll-free telephone lines or Web home pages can be designed to include meta-level tracking of the nature and topic of calls, providing cues that user documentation for certain products or services is inadequate. Because of transaction systems' increased flow and sources of messages, sent, stored, replied to, copied, and forwarded, there arise multiple opportunities for deception and manipulation, which are difficult to detect and even harder to hold any specific person accountable for (Zmud, 1990).

## 2.4 Sense-Making

Weick (1979, 1995) labels the state of confusion and uncertainty that can stem from complex problems as *equivocality* or *ambiguity*. Uncertainty may be resolved with sufficient information to find the right answer. However, equivocal problems have no single correct answer, although they may be resolved through joint creation of a shared meaning that makes sense to the participants.

Weick's theory of organizing identifies four sets of interlocking processes, constituting organizational sense-making to reduce equivocality. Sense-making begins with *ecological change*, sensed directly or relative to some prior measure, which presents equivocal information. *Enactment* is the process whereby individuals create their environments through attending to and interpreting certain phenomena, while ignoring, avoiding, or not perceiving other phenomena. For example, often the nature of work and organization must be reconceptualized to take advantage of the potential of a new practice or technology [such as word processing (see Johnson and Rice, 1987), or the office copier (see Brown and Duguid, 1996, p. 76; Orr, 1996)]. Then participants *select* a suitable explanation from possible alternative explanations of the enacted environment. Selections that appear to be useful are *retained*, through storage, acting, and evaluating, for future use—thus generating organizational routines. People typically engage in several cycles to reduce equivocality regarding a particular problem or issue. Each of these cycles typically includes an act, an interact, and what Weick (1979, p. 74) refers to as a *double interact*, where the initiator adjusts or responds to the second person's response to the initial action or communication. Thus, within the sense-making framework, Weick conceptualizes organizational structure as a communication activity of interlocked behaviors: an ongoing, cyclical process. The double interact highlights the crucial role of communication in human factors design.

## 2.5 Messages As Managing Meaning

In summary, the simple transmission models of communication ignore the critical need to understand the

*management of meaning.* Messages may complicate rather than simplify, obfuscate rather than clarify: possibly intentionally, and possibly even usefully. They vary in content, interest, and importance, they come through different channels, they create different patterns of response, and they link networks in different ways. A message may have different meanings and effect depending on the source, the channel, the receiver, or the context, including past experience, cultural identification, timing, and relational dynamics. Humans communicate through socially constructed and adapted symbols, and because both those symbols and interpretations have wide flexibility and evolve over time, the extent and nature of the relationship between the sender(s) and the messenger(s) heavily influence what meaning is associated with that process (Axley, 1984). Thus, a "message" really represents a wide variety of possible participants, situations, interpretations, and influences, and their interactions, both within the design process and within the use process. Before we explore the interactive processes associated with joint sense-making, in the next section we address the communication artifacts that produce and are produced through interaction.

### 3 COMMUNICATION ARTIFACTS

As Figure 1 indicates, we are emphasizing the communication relations among designers, among users, between designers and users, and with the "system" only insofar as the system itself mediates communication among these participants. In this sense, information and communication technologies are particularly interesting human factors artifacts, because they play a role both in communicating about innovations (as media) and are an innovation (a new system) themselves (Rice, 1987). As media, they are channels for communication. Thus, their use influences access to, the timing of, and the meaning socially constructed by, communication. As systems, they are the content (or topic) themselves, such as the "new system" or the innovation an organization is attempting to implement. Thus, their use can influence the nature, pattern, and extent of social interaction.

#### 3.1 Communication Modes, Media Richness, and Affordances

Potentially significant aspects of new computer-mediated communication systems for human factors include the ability to overcome constraints of time and place, to retrieve and search for associated material, to reprocess and merge different content, and to support many-to-many communication flows (Rice, 1987). However, debate continues as to how suitable or effective new media such as electronic mail, Web pages, mobile phones, and voice mail are for various communication activities, as compared to traditional media such as face-to-face or telephone.

Gibson (1979) introduced the concept of *affordance*, a possibility for action available through characteristics and uses of objects (in particular, technologies and media). Hartson (2003) extended the

concept's domain by distinguishing cognitive, physical, sensory, and functional affordances. For example, paper has many different affordances, especially in combination with other technologies (such as pens or thumbtacks), supporting a wide variety of human actions (Sellen and Harper, 2003). Paper documents allow readers to make notes or other marks on them, allow flexible navigation and manipulation, allow users to position or lay out the paper for different purposes, view material in much greater resolution than on-screen, are tangible (involving hands, eyes, and varying position), facilitate the coordination of action among organizational members, provide a medium for information gathering and exchange, support discussion, allow annotation for later discussion, provide a medium for organizing one's thoughts and work processes, and enable storage of information for multiple people, groups, locations, and time periods. Each medium or system thus has a wide range of characteristics and affordances, which may be more or less appropriate and more or less valued, across contexts (Rice, 1987).

Mediated communication faces challenges of supporting both the affordances of familiar media as well as multicue interpersonal interactions and adjustments. Mediation affects first impressions, the extent to which context can be shared, the scalability of participants, the types of interactions, attention, and exposure, formal and informal relationships, access to knowledge and status, accountability, possibilities for reducing misinterpretations, and so on.

*Media richness theory* (MRT) is frequently applied to this question of choice and effectiveness (Daft and Lengel, 1986; Trevino et al., 1987). MRT proposes that communication media differ in the extent to which they (1) can overcome various communication constraints of time, location, permanence, distribution, and distance; (2) transmit the social, symbolic, and nonverbal cues of human communication; and (3) convey equivocal information. As noted above, uncertainty can potentially be reduced by more information, if only the information can be found, perhaps through a "lean" computer database. However, one "make sense" of an equivocal situation, perhaps through "rich," iterative, negotiated discourse with other actors (Daft and Weick, 1984; Weick, 1995). Use of any communication channel involves both costs and information-processing capabilities, so a medium that is not well matched to the requirements of uncertainty or equivocality will degrade communication performance. Considerable research so far has shown some, although weak, support for this essential proposition. For example, Lind and Zmud's (1991) study of communication between information systems and noninformation systems personnel showed how matches between situation and communication channel affected technological innovation in the firm's business activities.

However, many studies find considerable differences between benefits from, reasons for choosing, applications of, and problems with new media, such as e-mail and voice mail. These studies seriously

challenge the simple unidimensionality of "media richness" often used to place e-mail at the lower end of media choice (Rice, 1992). Expanded and alternative models suggest that a communication technology's impact on communication is not simply a function of the task that information processing demands but also of time, critical mass, social influence, group identity and norms, technology adaptation, and experience with both the medium and the communication participants (Hiltz and Turoff, 1981; Rice and Aydin, 1991; Walther, 1992; Markus, 1994; Lea and Spears, 1995; Orlikowski et al., 1995; Carlson and Zmud, 1999).

### 3.2 Effect of System Design on Communication

Systems, and people's behaviors with and around systems, are deeply embedded in wider social and environmental situations (as argued by activity theory, situated action theory, and distributed cognition theory; Engestrom et al., 1999; O'Hara et al., 2003). Thus, systems, media, space, movement, gesture, people, and work are all interrelated in everyday communication (Chalmers, 2004, p. 74). Artifacts (new systems, as well as familiar furniture, paper, office accessories, and clothes) "communicate information about the organization and the people who work there" (Davis, 1984, p. 277).

Because the work environment affects individuals' attitudes, behavior, perceptions, and communication, people should be able to personalize and change their systems (Barker and Associates, 1978; Zalesny and Farace, 1987). Therefore, system designs should consider how spaces, communication, media, and people can be adapted, coupled, and intercontextualized "to form resources for social interaction and interpretation" (p. 76). For example, a basic attribute such as a display's physical orientation may have considerable implications for human communication. Using a vertical display for group interaction tends to create an authorial atmosphere, with someone controlling the display as a teacher or lecturer; however, horizontal tabletop displays "provide a natural centre for interaction to take place around and encourages collaboration between the users" (Stahl and Wallberg, 2004, p. 53). The location and formatting of office paper (such as binders, or Post-It notes) can signal whether someone should attend to it quickly or whether it can be shared (Sellen and Harper, 2003). Long-term use of video-mediated communication can foster complex patterns of interaction constrained by the features and structures of the new medium (Dourish et al., 1996). Major factors affecting communication interactions through video and audio systems include quality of audio, audio feedback and interference, self-views, awareness of range of shared users' fields of view, "reciprocity of perspective" (Bullock, 2004, p. 147), video refresh rate, conventional eye-gaze direction, proportional size of people in background, and audio or video access by people at periphery. For a more sociological example, the telegraph allowed people to communicate across time and space at a pace and amount never before experienced, but also

enabled railroad companies to collect, associate, and analyze information from stations about the dynamics of trains, shipments, and passengers. This transformed how organizations collected and processed information, located headquarters and branches, and how they learned from that information to develop effective schedules, routing algorithms and billing procedures, which changed the domains and design of railroads (Beniger, 1986; Yates and Benjamin, 1991).

Even the physical structures of buildings and offices create considerable constraints on communication, and thus quality of work life, performance, and innovation (Allen, 1977; Johnson, 1993). Physical environments within organizations represent material, although subtle, constraints on behavior, interaction, and possible interpretations. Influential aspects of physical environments include social density, proximity, access, exposure, privacy, mobility, time-space paths, physical structure (architectural and construction choices), physical stimuli (artwork, noise), and symbolic artifacts (office size and windows) (Archea, 1977; Davis, 1984; Johnson, 1993). Physical elements not only facilitate and constrain activities and relations, but often represent particular resources and contexts (consider the familiar concept of the influence of "the water cooler" on emergent relations and communication climate). Physical and temporal distances constrain network relations, increasing the costs of signaling one's interests and of finding people with similar interests (Feldman, 1987). Indeed, some researchers "view space as equivalent to context in providing the medium within which social interaction is embedded" (Johnson, 1993, p. 93).

Developments such as modular offices, shared displays (O'Hara et al., 2003), mobile communication, inhabited information spaces (Snowdon et al., 2004), and personal locator badges (Want et al., 1992) may overcome some of these constraints while generating others. For example, a study of a networked desktop video conference system showed that while it facilitated R&D workers' ability to make contacts and collaborate with others across offices, it still raised issues concerning norms of privacy, interruption, and access (Fish et al., 1993).

Many unanticipated problems and failures with automated systems are related to human-system interactions. Users may have difficulties tracking the system's activities, leading to "automation surprises" for both users and designers (Woods et al., 1997, p. 1927), for a variety of reasons:

1. New systems may help decrease workload in already low-workload conditions, but become distracting or harmful in pressured, critical workload situations, or create new work for different actor roles.
2. Systems may not indicate where or when to look for changes or disconfirming information, especially in rare or crisis situations, so users may not be allocating their attention appropriately, leading to breakdowns in attention to either (or both) the system and the situation.

3. Complex interdependent systems requiring varied inputs may foster mode errors when what might be an appropriate action in one system mode might be inappropriate in another mode and is made worse when the user is not aware of the shift. Indeed, taking action during a second mode while assuming the initial mode may generate internal parameters that activate a third mode, thus generating more unintended and difficult-to-identify consequences.

4. As the increasing demand for coordinating the various automation processes as well as human interactions exceeds one's abilities, supervisors or users may exit the automation system, or the system may reach its autonomy threshold and return full control to the operator, just at the time that the automation system is both generating and monitoring complexities that humans cannot process. The operator is likely not even aware of the underlying crisis, is unprepared or unable to handle the situation, and is thus surprised or shocked to find out the seriousness of the underlying problem.

5. Users come to rely on automation that are highly reliable for expected situations, but may fail in rare situations. Thus, they may overtrust systems, so systems should be designed to communicate its intentions, so that users have realistic and appropriate expectations. A system is a medium through which designers communicate their intention and into which users must responsibly place their trust (p. 1935, referring to Winograd and Flores, 1986).

The greater the levels of system authority and autonomy, complexity and number of components, and coupling among components, the greater the need for communication and coordination among users and between users and system to foster observability or awareness of the primary system as well as of other (social and technical) systems and tasks.

#### 4 COMMUNICATION CHARACTERISTICS OF PARTICIPANTS

The role of individual differences in human performance has been well documented in the physiology, psychology, and human factors literature (Salvendy, 1997). Communication traits, attributes, skills, and knowledge that differentiate communicative performance thereby have significance for user and design profiles are plentiful. These individual differences can range from communicative apprehension (Richmond and McCroskey, 1998) to nonverbal sensitivity (Hall et al., 1997), bargaining styles (Putnam, 1994; Putnam and Kolb, 2000) to framing (Fairhurst and Sarr, 1996), conflict styles and argumentativeness (Infante et al., 1984) to general communicative competence (Westmyer et al., 1998). Indeed, there is strong empirical evidence that personal communicative profiles influence perceptions of and performance with systems, and among designers and users. However, within this vast theoretical, research, and applied domain, the relationship between particular communicative characteristics and human factors is relatively undeveloped. Using illustrative

exemplars, we suggest behavioral impacts of several communication characteristics.

#### 4.1 Demographic Differences

Differences in communication styles, decoding and encoding nonverbal behavior, eye contact, proxemics, haptics, verbal aggressiveness, conversational style, and so on, have been well documented in demographic groups according to gender, race, ethnicity, nationality, and age (Tannen, 1990; Hofstede, 1991; Allen, 2004). Although the emergence and range of these demographic differences in communication is hotly debated (e.g., Buzzanell, 2000), and the artificial construction of these social identities has been critiqued (Allen, 2004), the practical importance of understanding the relationship between communication and demography is undisputed. We consider only gender and culture here.

##### 4.1.1 Gender

The recent growth in studies of gender, communication, and technology have important implications for human factors work. In general, these studies suggest that the gendered differences in communication found in face-to-face communication, such as nonverbal sensitivity preferences for collaboration and power sharing, are typically replicated in the interface between humans and technology (Ebben, et al., 1993). Dennis et al. (1999) found that matching richness of media to task equivocality results in better performance only for all-female teams, because, they suggest, females tend to be more sensitive to nonverbal communication and more affected by its absence in computer-mediated communication. Further, the gendered patterns of interaction associated with both formal and informal group meetings such as men gaining the speaking "floor" more often, and keeping the floor for longer periods of time regardless of their status in the organization, are also found in computer-mediated communication (CMC). Sutcliff (1998) found that messages on female-oriented Web sites emphasized communality, stressed personal experience, resisted authoritative language, and encouraged emotional interaction. In contrast, male-oriented sites emphasized privacy, stressed professionalism, relied on authoritative language, and minimized personal interaction. Herring (1994) also found that contrary to the claim that CMC neutralizes distinctions of gender, the patterns of interaction in postings to the Internet were recognizably different for women and men. Electronic messages posted to discussion groups by men were more likely to be written in an aggressive, competitive style, while women's messages tended to be more supportive. Furthermore, she found that women and men have different "communicative ethics"; that is, they value different kinds of online interactions as appropriate and desirable.

It is important to note, however, that there are many studies in which the communication context may be more important in predicting and modifying performance than demographic variables such as gender. For example, in a series of studies, Buzzanell and Burrell (1997) found that metaphorical schema

and linguistic cues used by conflict participants was associated with the type and context of conflict rather than demographic characteristics.

From a human factors perspective, the demographic stereotypes that users and designers use when entering a communication situation are also critical to consider. For example, although research has not consistently confirmed that women and men differ in the frequency of their use of tag questions, disclaimers, and other communicative forms which decrease assertiveness and effectiveness, women are perceived to communicate in this more deferential style, so violations of those expectations have serious implications for women's power and efficacy in a system (Tannen, 1995). Stereotypes of Asian Americans as passive and docile have also been found to impede career advancement (Woo, 2000).

#### 4.1.2 Culture

Globalization and the increasing diversity of today's workplace make the study of cultural differences and communication processes ever more critical for human factors work (Stohl, 2001). Hofstede (1980, 1991), the primary proponent and developer of measures of *national cultures* and organizational values, defines culture as "the collective programming of the mind which distinguishes the members of one human group from another" (Hofstede, 1984, p. 210). He originally identified four dimensions of cultural variability (power distance, uncertainty avoidance, masculinity, and individualism) and in 1988, added a fifth dimension, Confucian dynamism (Hofstede and Bond, 1988), rooted in principles of stability, status, thrift, and shame.

All the dimensions of cultural variability reflect the differing values given to issues of equality, ambiguity, instrumentalism, and community and are strongly associated with the ways in which people across the world perform roles, communicate, relate to one another, and utilize communication technologies (Teboul et al., 1994). In high-power-distance countries such as Singapore, the Philippines, France, India, Venezuela, and Portugal, employers and employees are more likely to consider that violating the chain of command constitutes serious insubordination. Low-power-distance countries such as Denmark, New Zealand, and Israel expect people to work around hierarchical chains and do not see hierarchy as an essential part of organizational life. When working in or with high-power-distance countries, Hofstede suggests, it is important to respect the authority structure and show deference to the formal hierarchy. In low-power-distance countries, organizations tend to be less formal and have more open communication across the social system (Hofstede, 1984).

Driskill (1995) substantiated these conclusions in a study of Euro-American and Asian-Indian engineers. American and Indian co-workers identified situations involving authority, role duties, and supervision as the most salient contexts for the emergence of strong cultural differences. Asian Indians felt that competent supervisors should provide daily

and direct surveillance, were very comfortable with an authoritarian decision-making style, and accustomed to strict adherence to job descriptions and titles.

It is important to note that despite the valenced stereotypes people may hold about particular national cultures, no particular level of cultural values is better or worse than others, although they may be associated with norms or behaviors inappropriate in other cultures. For example, Hofstede notes the negatives of both ends of the individualism/collectivism dimension: the selfishness of individualism and the tyranny of collectivity.

In more individualist societies, "the ties between individuals are loose; everyone is expected to look after himself or herself and his or her immediate family. ... Collectivism ... pertains to societies in which people from birth onwards are integrated into strong, cohesive ingroups, which throughout people's lifetime continue to protect them in exchange for unquestioning loyalty" (Hofstede, 1991, p. 51). Earley (1993) found that collectivists' performance was lower than that of individualists' under conditions of working alone, or working in an out-group, compared to working with an in-group. Collectivism's emphasis on tradition may also limit the extent of new technology transfer (Hofstede, 1980, p. 218), such as implementing and using new computer-based communication media.

Individualism and collectivism also are related to concepts of low-context and high-context cultures (Gudykunst and Kim, 1992). In *high-context cultures*, most of the content of messages is embedded in the communicative context rather than the denotative content, in nonverbal cues, in relational cues and group membership, or in indirect messages. Meaning is often internalized, creating a greater responsibility for the receiver to intuit the appropriate interpretation. These differences would imply that people from collectivist cultures might prefer richer media and possibly interpret situations as being more equivocal, unless the situations place the responsibility for interpretation on the receiver (such as when the receiver is a subordinate). Rice et al. (1998) found that approximately 400 respondents from two "collectivist" countries rated the telephone as less rich, and the business memo as richer, than did respondents from two "individualist" countries, but there were no significant differences in evaluations of e-mail, meetings, and face-to-face communication, and no differences in relationships between task equivocality and media preferences across the two cultural types.

#### 4.1.3 Intercultural Communication

The communicative adaptation and accommodation necessary in cross-cultural encounters has long been studied in psychology, communication, and business (Hall 1981; Black and Mendenhall 1990; Gudykunst 1991; Triandis, 1994; Giles and Noels 2001). Participants of multinational groups—groups that transcend any single culture and produce new, effective, and efficient systems of interaction—must recognize, empathize with, understand, and address

## COMMUNICATION AND HUMAN FACTORS

cultural differences, develop a shared vision or superordinate goal, develop mutual respect, and provide feedback in culturally sensitive ways (Adler, 1980; Harris and Moran, 1999).

With the increasing globalization of organizational and technological processes, intercultural communication has become an even greater focus of employee training and design (Galarneault, 2003; Landis et al., 2003) and for participants in global e-learning (Marinetti and Dunn, 2002). Most training in intercultural communication has cognitive, affective, and behavioral components designed to sensitize individuals to their own cultural blinders and to increase awareness of cultural differences. Training modules tend to include a combination of lectures, cultural assimilators, case studies, role-playing, self-awareness and attributional questionnaires, experiential simulations, analyses of popular culture, and live demonstrations of intercultural encounters (Brislin and Yoshida, 1994; Galarneault, 2003). Generally, intercultural communicative competence consists of knowledge about and sensitivity toward cultural differences, awareness of one's own and others cultural responses to interactive sequences, attitudes that promote openness, and basic behavioral and relational skills (Porter and Samovar, 1991; Chen and Starosta, 1997). A Google search of "measures of intercultural competence" yielded 16,100 entries alone!

It is also important in the design and implementation of technologies and quality and safety processes to take account of the native language of participants, not just the language in which interaction is taking place. For example, Choong and Salvendy (1999) have explored the design of icons and computer interfaces for Chinese language users. Bantz (1993) found that although cross-national research teams usually agree on a working language, differences in language competence, comfort in working in a nonnative tongue, and nontransferability of some abstract concepts, sometimes minimized the contributions members could make to the team and strongly affected conflict management and the emergence of norms. Analyzing the discourse of both English and Spanish versions of a meeting between a hotel general manager and 75 workers whose dominant language is Spanish, Banks and Banks (1991) illustrate the many ways in which the translation process not only provides a conduit for information transfer but creates a set of interactive and relational issues based on power and context which influences how messages are interpreted.

Clearly, intercultural communication is not only about the accurate transfer of messages. It entails sense-making and meaning construction as well as active production of interpretive frames.

### 4.2 Communication Styles, Cognitive Complexity, and Message Design Logics

Communicator style reflects recurring patterns of communication behavior by which one verbally, nonverbally, and paraverbally interacts to signal how literal meaning should be taken, interpreted, filtered, or understood (Norton, 1983). Within the

communication literature, 11 communicator styles have been grouped according to two underlying dimensions: nondirective (attentive/friendly) vs. directive (dominant/argumentative) and low energy (relaxed) vs. high energy (dramatic/animated). Communication styles are related to leadership performance, teaching effectiveness, conflict management, decision making, relational development, and gender equity. To the extent that interactants prefer or exhibit specific styles, they may have more or less effective and satisfying communication with each other or interactions with and through systems. Communication styles are also associated with individuals' attitudes toward technologies. For example, a study of two organizations found that people with more relaxed and friendly styles were more likely to adopt and use e-mail. "Individuals with communicator styles that involve taking the time to think about and respond to others ... may find email systems supportive ... because they can consider the others' communication without the pressure to respond immediately or lose conversational turn. Aspects of the friendly style (such as 'habitually acknowledging others' and 'encouraging others') and the attentive style ('repeating' and 'deliberately react') represent aspects of email message responses that could motivate other users to return more messages" (Rice et al., 1992, p. 23).

A highly developed and focused research program related to individual differences and communicative performance is associated with constructivism and *cognitive complexity* (Delia et al., 1982). Early constructivist research demonstrated that people differ in the degree to which they develop complexity in social cognition, which in turn affects their ability to take the perspective of the other, manage interactions and be effective at accomplishing both instrumental and relationship goals. Over the years, cognitive complexity has been associated with the ability to acquire, organize, and integrate social information (Sypher, 1991); the ability to produce sophisticated, behaviorally complex message forms that are both interpersonally sensitive and pragmatically effective; the ability to interpret and comprehend the messages of others (Hynds, 1985); and the ability to manage conversational interactions in a coherent and effective fashion. Several studies (e.g., Sypher et al., 1989; Penley et al., 1991; Zorn, 1991; Zimmermann, 1994) suggest that cognitive complexity is an asset in the work environment. Cognitive complexity has been linked to a person's ability to design effective and persuasive messages that are adapted to different audiences and address multiple goals (O'Keefe et al., 1993).

Humans use three *message design logics* (O'Keefe, 1988). People who employ an *expressive design logic* believe that communication is a little more than a process to express what they feel. They create verbal messages with few goals in mind other than the declaration of fact, emotion or attitude. People who operative within this logic often seem to lack an "edit" function, their communication tends to be socially inappropriate, overly blunt, and may express shockingly personal remarks. O'Keefe (1988)

finds that expressive message producers often do not see messages as open to multiple interpretations or able to accomplish multiple goals. In a *conventional design logic*, communication is considered to be a cooperative enterprise based on socially conventional rules and procedures, intended to achieve desired social effects. Within interactions, people employing this logic are quite responsive to the social and normative "demands" and expectations created within the sociotechnical system. In a *rhetorical design logic*, communication is the construction and negotiation of social selves and situations. Instead of altering their communicative actions to fit the situation as a conventional message producer might, rhetorical logic users alter the situation to fit the action they want to perform. Thus, people employing conventional logic react to context, but rhetorical logic users understand that they help create the context to which they then respond. Interactants may use different message design logics. Thus, two expressives with different opinions or goals may find it difficult to connect, while a rhetorical receiver may overestimate the systematicity of an expressive's message, possibly perceiving inconsiderateness and uncooperativeness (O'Keefe et al., 1997, p. 42). Making sense and coordinating action can become even more difficult when design team conflicts lead some expressive members to use only e-mail as a way to avoid interacting with specific others and to attempt to send clear messages, but thereby allowing others with conventional or rhetorical design logics to interpret the messages in multiple ways.

### 4.3 Communication and Work Roles

Roles comprise the actions and activities assigned to or required or expected of a person or group. People occupy different work and social roles. These may be the familiar *organizational position* or division of labor, such as manager, secretary, shopworker, or systems analyst, whereby duties, goals, and obligations differ because of organizational hierarchy, job tasks, and experience. Roles may involve belonging to different professions—such as engineer, accountant, consultant—or organizations—such as members of a cross-organizational project. Roles may involve different stages of problem solving, such as designer, coder, marketer, implementer, trainer, or user. Or as discussed below, roles may be locations in a communication network such as a gatekeeper or isolate.

People in these different work roles are likely to have different communication needs and media use patterns. There are at least three general reasons for this. First, different positions have different tasks and roles. So, for example, people higher up the organizational hierarchical, especially higher-level managers, have more equivocal activities involving multiple roles, so they engage in much more oral (vs. written) communication—the position affects their communication (Mintzberg, 1980; Rice and Shook, 1990). Mintzberg (1980) identified three

categories of 10 interrelated managerial roles: interpersonal, informational, and decisional. *Interpersonal roles* (figurehead, liaison, leader) use authority and status in interpersonal relationships. Managers also perform crucial *informational roles* (monitors, disseminators, spokespeople) pertaining to the flow of non-routine information crucial to decision making. Being an "information nerve center" enables and requires the manager to carry out *decisional roles* (entrepreneur, disturbance handler, resource allocator, negotiator). The organization's environment may foster particular roles (Gibbs, 1994).

Second, people may have different communication skills, abilities, and preferences that are more or less appropriate for types of positions—the person is drawn to or selected by the position because of this fit. Early work on computer displays found that people from different professions or positions tended to prefer different graphical data formats (such as tables, charts, and figures; Ives, 1982). Or consider the issues of communicator style, cognitive complexity, or message design logics describe above.

Third, one's organization and profession may socialize or train the person into appropriate communication behaviors and preferences; the context helps the person adapt to the position (and vice versa). Organizations may well have both underlying common (such as meetings) as well as different (such as e-mail vs. voice mail) relationships between positions and media use patterns (Rice and Shook, 1990).

### 4.4 Organizational Culture

As suggested above, all communication is embedded in the larger social system that must be considered in any human factors design. *Organizational culture* is often used to mean the shared meanings, patterns of belief, symbols, rituals, and myths that both support and limit organizational participants in defining and responding to situations, fostering a communal identity and shared expectations for generally approved behavior. Generally, these aspects of culture are latent and implicit rather than overt and explicit, although socialization processes, regulations, codes, policies, and manuals may attempt to represent, or maintain, some aspects of culture. Schein (1994) says that the strength of any particular culture is a function of (1) initial convictions of organizational founders, (2) the stability of the group or organization, (3) the variety and intensity of learning experience, and (4) the extent to which the learning process avoids anxiety vs. positively reinforced change. And, of course, there may be multiple subgroup cultures, inside and outside the organization, and individuals may belong to multiple subgroup cultures.

Although most interpretive or critical researchers would dispute that culture can, or should, be measured through surveys, or even managed in any way, there are many reliable multidimensional culture assessments, usually grounded in a specific conceptualization of organizational culture (Glaser et al., 1987; O'Reilly et al., 1991; Cameron and Quinn, 1999). For example, Cooke and Szumal (1993) propose a dozen

normative beliefs that are associated with different behavioral expectations, leading to a dozen different cultural styles: affiliative, approval, conventional, dependent, avoidance, oppositional, power, competitive, perfectionist, achievement.

Organizational culture may fundamentally influence how systems are used, or even whether and how they are designed and adopted. Schein (1994) first makes the familiar claim that an innovative culture is necessary for achieving the potential of new information systems (whether new products or services, or new ways of doing things and defining roles) in organizations. But he then argues that the underlying vision of system designers—their culture—significantly affects how systems are conceptualized, designed, and used. For example, systems can be used simply to automate, or to informate (provide information from system processes to users and managers to learn about the processes; Zuboff, 1985), or to transform the organization (work, communication, authority relations). As we have suggested, information and communication technologies can be conceptualized as both media and content of innovation. Thus, they can also be used to help unfreeze organizational cultures to promote more innovative systems, through the characteristics of accessibility, rapidity, simultaneity, presentational flexibility, complexity, system awareness/informing, system and network accountability, teamwork capacity, task-based authority, and self-designing capacity, thus supporting collaborative teamwork and enabling alternative coordination methods (Schein, 1994).

Organizations may have more or less supportive information-sharing cultures, affecting what kinds of systems can even be discussed, how they are designed, what features are available to different users, and how learning about a new system is facilitated or suppressed (Dewhurst, 1970–1971; Pettigrew, 1972; Johnson and Rice, 1987; Rice et al., 1999). These norms affect knowledge sharing, whether the knowledge is personally or organizationally owned and whether the sharing is internal or external (Jarvenpaa and Staples, 2001). Indeed, there is no specific isolated knowledge, but rather, a *situated knowledge web*, as knowledge is embedded in individuals, connections between individuals, and artifacts (Nidumolu et al., 2001). A “quality management” corporate culture would influence the nature, form, and frequency of communication within an organization and with its customers (Fairhurst, 1993), and both locates and legitimizes measures such as customer satisfaction or error rates.

Perhaps a more fundamentally communication-oriented approach to organizational culture is Lakoff and Johnson’s (1980) argument that how we perceive the world, and thus how we behave, is influenced fundamentally by the metaphors we have access to and use (see Stohl, 1995, for a discussion of organizational metaphors). Three main groups of metaphors shape these perceptions and behaviors: structural, orientational, and ontological. For example, orientational metaphors organize concepts relative to each other through spatial or geographical forms (the system is “up”; “downloading” data).

## 5 GROUP COMMUNICATION

Given their importance and the advantages of groups/teams for organizational effectiveness, it is not surprising that human factors is concerned with how to design and implement effective teams. Rather than focusing on member selection and group composition, we emphasize the communication processes that comprise the group experience. For example, many practitioners utilize specific communication techniques that are designed to control the process and lead groups to more effective interaction. These processes can be supported and improved through *hardware* and *software technologies* (group decision support and communication systems, e-mail, collaborative authoring, etc.). But more important is understanding the range of *social technologies* also available to support and improve group communication (such as among designers, or between designers and users).

### 5.1 Group Process Losses and Gains

Group communication has both advantages (gains) and disadvantages (losses) compared to dyadic communication (Steiner, 1972; Nunamaker et al., 1991). *Group process gains* include more information (greater access and diversity of knowledge), synergy (fosters different uses of information), more objective evaluations (as others can catch errors), stimulation (greater motivation and encouragement), and learning (via observation of and practice with skilled members).

*Group process losses* include air time fragmentation (dividing up speaking time); attention blocking (group members are prevented from contributing comments as they occur, forget or suppress them later in the meeting); cognitive inertia (bias toward one train of thought); conformance pressure (due to politeness norms or reprisal fear); coordination problems (difficult to integrate members’ contributions, leading to cycling or premature decisions); domination by some member(s); evaluation apprehension (members criticize and censor their own ideas before stating them); failure to remember (others’ contributions, or topic); free-riding/social loafing (as not everyone can or must participate, whereas all can benefit, others conclude that their contributions are dispensable, and reduce their effort); incomplete task analysis; incomplete use of information; information overload (speed, amount, and diversity); production blocking (only one member can speak at a time, blocking others’ ideas, either because the others forget their ideas, are spending time rehearsing their own idea, which reduces new ideas, or most commonly, simply prevents other ideas from being discussed because of time limitations); production matching (performance norms develop, so exceptional ideas are suppressed); social facilitation/inhibition (some may facilitate performance if the task is simple but inhibit it if it is complex); and socializing (although some is necessary for effective group maintenance).

*Groupthink* can be thought of as a group process loss whereby members of highly cohesive groups that place greater value in mutual attraction, or

on acceptance by the leader, than on high-quality decisions. This drive for internal group maintenance suppresses alternative positions or information, ignores flaws in solutions, and labels challengers as betraying group norms (Janis, 1982; Whyte, 1989). Groupthink generates an overestimation of the invulnerability and morality of the group, negative stereotypes of out-groups, joint rationalizations, and pressures toward uniformity (via self-censorship, false sense of unanimity, and pressures against challengers). It is easy to imagine how a system design group with considerable history and professional allegiance can fall prey to such a process.

### 5.2 Communication Skills

Group members should be trained in a wide range of skills, such as initiating, questioning, interpreting, suggesting, facilitating, evaluating, receiving and giving feedback, clarifying, summarizing, closing, active listening, confronting, blocking counterproductive behaviors, modeling, reflecting feelings and supporting, and empathizing (Shockley-Zalabak, 1998). Gouran (1982) develops an agenda for *vigilance* that is designed to prevent symptoms of groupthink from arising. Stevens and Campion (1994) identified five areas (involving 14 different sets of knowledge, skills, and abilities) affecting group member performance: conflict resolution, collaborative problem solving, communication, goal setting and performance management, and planning and task coordination. Group leaders may use, exhibit, or be unaware of a variety of communication tactics, such as authoritarian (block ideas, control process, announce goals, punish others), participative (seek ideas, facilitate, encourage disagreement, seek idea evaluation, verbalize consensus), avoidance (ignore conflict, change subjects, agree with others, refuse responsibility), vision setting (visualize abstract ideas, state desired outcomes; articulate reasons), meaning management (solicit feedback, generate symbolism, manage meaning), trust (communicate constancy, identify values, encourage access), and positive regard (provide support, offer praise, avoid blame, identify challenges) (Shockley-Zalabak, 1998). These skills are needed, in various combinations, in both *group task roles* (problem analysis, idea generation, idea evaluation, vision identification, solution generation, solution implementation, goal setting, agenda making, discussion clarification, disagreement identification, and consensus identification) and *group maintenance roles* (group participation, group climate, conflict management). Several group social technologies are discussed below.

### 5.3 Brainstorming

Both users and designers have a wide range of potential contributions, ideas, and contingencies that are relevant to developing and implementing a new system, but group process losses and poor group communication skills may suppress most of these. *Brainstorming* is designed to stimulate many, and diverse, ideas for consideration. The goal here is simply to generate as many ideas as possible as

quickly as possible, without any evaluation or regard for feasibility. Group members are encouraged to offer ideas during a short period of time—with no editing, evaluation, or comment by any member—which the group facilitator records. In subsequent group processes, this rich resource can be grouped, evaluated, ranked/prioritized, and allocated to committees for elaboration (Moore, 1994).

### 5.4 Nominal Group Technique

Extending the brainstorming technique, but avoiding public attributions or hesitancy, here participants are asked to generate silently and write down as many ideas as possible on the particular topic or problem. Then each person is asked, in turn, to contribute one (new) idea, which a facilitator records and may combine into related ideas. After all the ideas are recorded, the group then clarifies and discusses each idea, one at a time. Then the ideas are prioritized through ranking or voting (such as each member ranking the five most important ideas), possibly initially for indicating acceptance of the ideas. The final prioritized ideas are then the basis for further action (Wilson, 2002).

### 5.5 Delphi Technique

The *Delphi technique* elicits experts' views (about relevant criteria for a problem, or forecasting predictions, threats, or trends), through anonymous, asynchronous responses (now commonly done via Web pages or e-mail surveys) in several rounds until general consensus is reached (Linstone and Turoff, 1975). Communication among the experts is intentionally anonymous in order to encourage openness and equality, avoid group dynamics and individual domination, and reduce performance anxiety and the importance of oral communication skills. A summary of the results (means and standard deviations) for each question from the prior round, showing the distribution of opinions, is provided to identify areas of agreement and disagreement, which helps participants to reassess their own opinions, fostering a convergence to consensus. The *nominal group technique* is related, but the face-to-face group meeting usually involves just one round of anonymous voting.

### 5.6 Functional Theory of Group Performance

Besides particular techniques designed to improve group effectiveness, there are several theoretical frameworks that are useful for understanding and improving group performance. *Functional theory* (Gouran and Hirokawa, 1983) focuses on the systematic procedures that groups use to accomplish their tasks. The basic premise is that communication serves task functions, and the accomplishment of those functions should be associated with effective group problem solving and decisions. The general model is based on four decision-making functions: (1) the problem must be understood, (2) the requirements for the decision must be assessed, (3) the positive alternatives to the choice must also be assessed, and (4) the negative consequences must be analyzed. Communication

agendas or problem management sequences (Gouran and Hirokawa, 1983) are designed to make sure that group members' communication fulfills the needed functions so that they can choose an alternative based on the group's evaluation. Promotive communication calls the group's attention to the performance of a functional requisite. Counteractive communication refocuses a group's attention on a functional requisite after it has deviated away from it. A functional analysis can also be used to determine if the group's decision is "faulty" or inappropriate. There are five communication factors that can potentially lead a group to a low-quality decision: (1) the improper assessment of a choice-making solution, (2) the establishment of inappropriate goals and objectives, (3) the improper assessment of positive and negative qualities associated with the various alternatives, (4) the establishment of a flawed information base, and (5) faulty reasoning based on the group's information base.

Other communication theorists suggest that the assumptions on which functional theory rests limit their usefulness in understanding and improving group processes. For example, Stohl and Holmes (1993) argue that the theory needs to be reframed in ways that more fully articulate important features of bona fide groups (Putnam and Stohl, 1996) and thereby reflect the intricate and interlaced texture of collaborative work. For example, functional approaches take for granted that decision quality is an objective characteristic or attribute that is apparent at the time of the production of the decision, yet standards of effectiveness may depend on who does the evaluation and when the evaluation is done. Furthermore, the requisite task functions are only those that accomplish logical, rational group decisions. Yet communication functions to situate and embed a group and its definition of its task within its context as well as to create an interactive climate in which group cohesion may or may not develop. Hence, there are institutional, historical, and maintenance functions that also must be considered.

### 5.7 Adaptive Structuration

Poole and his colleagues (Seibold and Meyers, 1986; Poole and DeSanctis, 1990; DeSanctis and Poole, 1994) have applied *structuration theory* (Giddens, 1984) to group decision making in computer-mediated contexts. This work provides a significantly different perspective on group interaction. In structuration theory, a system is the social entity that gives rise to observable patterns of relations. Structures are the rules and resources that actors use to generate and sustain the system and are institutionalized by human action: "They are both the medium and the outcome of action. Interaction patterns—human action—become structural properties through repeated, habitual action, which are then referred to or applied through subsequent action. Structuration is the process by which systems are produced and reproduced through members' use of rules and resources" (p. 117). Structures include procedural structures (such as computerized group support systems), argument structures, and decision rules. This research program has been able to identify the

ways in which structures emerge, are appropriated and used by groups, and explore the ways in which structures help guide, constrain, and enable effective group action. Several schemes for identifying structuring moves, modalities of structuration, and general types of appropriations have been developed (DeSanctis and Poole, 1994).

Three sources of structures as preexisting conditions form the context in which the technology is implemented, and as such, affect appropriations, which in turn affect decision processes and outcomes. *Technology structures* include the restrictiveness, sophistication, and comprehensiveness of its features as well as the technology's spirit, the general intent of the technology with regard to values and goals. *Task and organizational environment* refers to the nature of the task (such as complexity and interdependence) and the organizational setting (such as hierarchy, corporate information, and cultural beliefs). The *group's structure* includes the interaction patterns and decision-making processes of its members. *Appropriations*, which may be subtle and difficult to observe, are the immediate, visible actions that evidence deeper structuration processes. Appropriations can be more or less faithful (the extent to which appropriations are in line with the technology's spirit), enable more or fewer instrumental uses, follow more or less the "spirit" of the designed features, and reflect more or less the users' attitudes. DeSanctis and Poole (1994) proposed that the more faithful the appropriation, the more likely the team's decision processes will lead to successful outcomes.

Majchrzak et al.'s (2000) analysis of a year-long virtual team designing a new rocket fuel thruster lead to a revised or extended model of structural adaptation. Structures suggested include technology, group, and organizational environment. Appropriation moves lead to decision processes, which in turn lead to (ideally, but not always, positive) outcomes. In addition, however, the effect of preexisting structures on appropriation moves is not direct, but is instead mediated by three factors: the degree of misalignment, the malleability of the structures, and the occurrence of discrepant events. However, these discrepant events are not necessarily discontinuous but, rather, occur potentially continuously over the life of an adaptation process (depending on the size, cost, and time frame). Moreover, the discrepant events do not necessarily result from preexisting structures, but may instead, arise from emerging events. The discrepant events can lead to increased misalignments instead of a necessarily gradual reduction in misalignments. Emergent structures are likely to occur, but these emergent structures may themselves create new discrepant events. Any of these structures—technology, organizational environment, or group—are inherently able to change in this structuration process; one should not be seen as necessarily any more constraining than another, although in a particular context any particular structure's malleability may be restricted.

Considering human factors, then, attitudes toward and uses of current organizational systems become structured by acceptable norms, evaluations, and

resources; attitudes and users are mediated by the systems themselves; and these structures in turn constrain or facilitate interpretations and uses of new systems (Orlikowski, 1992). The interpretations of new systems are constrained by earlier interpretations, perhaps by exaggeration or misunderstanding of its potential characteristics, comparisons to media artifacts, even by rationales for design choices that are now unknown by new users (such as reduced labor costs, a visionary supervisor, or strategic initiatives; see Johnson and Rice, 1987; Rice and Gattiker, 2000).

## 6 COMMUNICATION NETWORKS AND COLLABORATION

*Networks* are patterns of relations among entities within a system, considered by many to be the quintessential organizational form of the twenty-first century and the embodiment of flexibility, responsiveness, and efficiency. Network analysis is an important tool for enhancing human performance. A "new science of networks" has been heralded within the biological, physical, and communication sciences (Watts, 1999; Barabasi, 2002; Buchanan, 2002; Monge and Contractor, 2003) insofar as it has uncovered an underlying mathematical dynamic of interconnectedness, a common architecture of shared deep structural properties that strongly influence how we think and how we organize. The overall structure of a network, the emergence of new linkages, the relationships among the network members, and the location of a member within the network are critical factors in understanding and enhancing access to key resources, the distribution of social and organizational power, the spread of new ideas, the development and utilization of expertise and knowledge, and the identifications and motivation of workers (Miles and Snow, 1986; Monge and Contractor, 2003). The emergent structures of egocentric and organizational networks also strongly influence sense-making and interpretive processes (Stohl, 1995). For example, when people are enmeshed in a highly interconnected network, they tend to receive the same information and reading of a social situation over and over again, reinforcing the view that there is only one correct way to interpret messages and events. In contrast, when a person has a number of *weak ties* (i.e., people who they may not often communicate with and are not linked to many others in their own network), they often receive new and unique information (Granovetter, 1973). The diverse set of opinions, rationales, and positions suggest that there is more than one view of the situation. Weak ties can produce a more complex and complete view of information and messages.

### 6.1 Semantic Information Distance

Researchers in organizational communication have long been aware of the gap in understanding and/or information among specified homogeneous groups in organizations such as between management and labor, supervisory and hourly workers, rank-and-file union members, and union headquarters staff. Tompkins

(1962) termed this disparity of interpretation *semantic information distance*. Many scholars believe that homogeneity of attitudes and interpretations which produces serious differences in understanding is a logical by-product of cohesive groups because as members interact frequently with each other, they socialize one another, creating strong group norms, reinforcing like-minded opinions and conforming interpretations while challenging deviant opinions. Thus, designers see the world differently from hourly workers because each group is enmeshed in a very different set of network links and share their experiences. Other researchers suggest that people who are in the same types of groups (e.g., upper management, union) develop similar interpretations, not necessarily because they talk to one another but because they are *structurally equivalent* (Burt, 1983). That is, they develop similar behaviors and attitudes because they tend to interact with the same types of people in the same manner in the same types of context, so even though their networks may not include the same people, they include links in the same position with similar configurations and hence are similarly socialized by others.

### 6.2 Communication Network Nodes, Links, and Properties

Network nodes may be people, organizations, words, systems, events, and so on; the relations may be communication, trade, task interdependencies, system features, hierarchies, or others. The strength of such relations among the entities might be measured by frequency, attraction, length, dependency, or other entities. Typical organizational communication network roles include being a member of a group (or clique), the liaison (who connects groups but is not a member of any group), the bridge (who belongs to one group but provides a direct link to another group; this may include the *gatekeeper*), the isolate (who does not belong to any particular group), the opinion leader (to whom others turn for leadership and legitimization of group norms), and the boundary spanner, environmental scanner, or cosmopolite (who provides a link between the organization and the environment). Other roles include the broker (who passes information or resources along), a follower (who provides links to but not from others), a leader (who receives links from but may not provide links to other), and *structurally equivalent actors* (people who have relations similar to others in the network).

Network analysis can also characterize network properties of dyads (such as reciprocity and similarity in the network), triads (such as transitivity, the extent to which communication between project leader A and software engineer B, and a relation between A and software engineer C, also involves a relation between B and C), the network as a whole (overall density, centrality, integrativeness, power/prestige, reciprocity, transitivity), and other measures of structure, as well as cliques or positions within the network. Each of these variables provides important information regarding the capacity of the system to develop,

process, and utilize information, perform tasks efficiently, safely, and effectively, and respond to disruption and nonroutine events. For example, Krikorian et al. (1997) studied a satellite manufacturer as they attempted to improve performance by "reengineering" five processes generating specific problems: "redo" processes, non-value-added processes, splintered processes, lack of standardized metrics, and treating customers as outsiders. An analysis of the emergent technical, social, and organizational networks showed that these apparently separate problems were in fact quite interrelated; so any one isolated improvement might create further difficulties for one or more other processes.

### 6.3 Collaboration, Transactive Memory, and Knowledge Networks

Successful and effective work, especially research and development, requires obtaining, being exposed to, and interpreting information from and about others and about orientation contexts, whether known or unknown, intended or unintended, through multiple channels (Churchill et al., 2004). Software development especially requires coordination (Kraut and Streeter, 1995). Software development involves challenges of the scale of large projects (leading to a multiplicity of actors and their associated expertise, physical obstacles, problems of ownership, and unwillingness to trade information), the uncertainty in designing new products or software (identifying and solving errors, nonexistent or unavailable information, changing requirements, competing schedules), interdependence (because of the tight integration of project components), and the need for informal communication (to support spontaneous information exchange and context development, often provided inadequately via technical tools or formal procedures).

Thus, spaces and media should foster both awareness of, and spontaneous interaction among, both co-located and distributed users. Awareness (both direct and peripheral), notification, and spontaneous interaction media have received considerable, although not well-diffused research (Krauss and Fussell, 1990; Dourish and Bellotti, 1992; Jang et al., 2002; Kraut et al., 2003; O'Hara et al., 2003). Systems and interfaces must support awareness without being too explicit about it, provide summaries compiled relative to each user's "observation rhythm," indicate when something unusual happens that requires the user's attention, or allow overviews of past and current activities and participants (Prinz et al., 2004). These activities could be folders, Web sites, workspaces, procedures, sequences, documents, tasks, and so on.

In designing high-performing systems, it is important to build knowledge assets and to make sure that this knowledge is effectively identified, distributed, shared, and used. Contractor et al. (2002) have found that communication among group members not only provides the starting point for learning about others' expertise, but network dynamics are the basis

for coordinating who will learn what. Communication increases efficiency and reduces the redundancy of knowledge in the *transactive memory system* (Hollingshead, 1998).

Combining the tools of *network analysis* with their theory of transactive memory, they are able to predict how actors in a knowledge network acquire and select knowledge, based on what they think others know. For example, they identified knowledge brokers as those actors with high "betweenness" scores. In addition, they suggest that an actor whose cognitive knowledge network maps accurately onto the observable knowledge network is more likely to be identified as the one "who knows who knows what." One knowledge network system is IKNOW (Inquiring Knowledge Networks on the Web), a Web-based e-solution created to help systems manage their knowledge assets (Contractor et al., 1998). IKNOW "helps an organization by putting in place a mapping, visualization, and measurement system that can help organizations to study the patterns of knowledge and information flow through an organization's informal network. IKNOW will answer the following: Who knows who? Who knows what? Who knows who knows who? Who knows who knows who?" (<http://www.spcomm.uiuc.edu/Projects/TECLAB/IKNOW>).

## 7 COMMUNICATION ENVIRONMENTS AND INNOVATION

### 7.1 Assessing Communication Environments

As organizations are systems of interdependent subsystems—in Weick's terms, organizing processes constituted through interaction—research shows clear relationships between appropriate organizational communication and performance, innovation, and working conditions. These relations operate through information sharing, participation and commitment, seeking suggestions, delegation, connectedness and social support, fewer worker disputes, more positive organizational climate, communication satisfaction, job satisfaction, better understanding of work, and increased certainty (Hargie and Tourish, 2000). Thus, organizational designers (i.e., designers of systems, the social groups designing systems, and managers of relationships with users) must understand, assess, and improve organizational communication.

There are well-established and widely used surveys to assess these organizational concepts. Components of communication satisfaction may include climate, relation to superiors, organizational integration, media quality, horizontal relations, organizational perspective, relation with subordinates, personal feedback, job satisfaction, productivity, managerial communication competence and style, conflict communication, group and team communication, communication load, mentoring, organizational commitment, organizational identity, subordinate trust for supervisor, gatekeeping, job characteristics, leadership style and development, and so on (Roberts and O'Reilly, 1979; Mills et al., 1988; Downs 1994b).

They may be integrated as part of what is usually called an *organizational communication audit* (Downs, 1994a; Hargie and Tourish, 2000). Organizational communication concepts, especially audits, are part of a systematic approach to constructing both internal and external communications strategies, and require rigorous evaluation of all steps (Hargie and Tourish, 2000). Goldhaber and Rogers's (1979; Goldhaber, 2002) approach includes amount of information received, amount of information sent, amount of follow-up, amount received from a range of sources, amount received through channels, timeliness of information, organizational relations, and satisfaction with organizational outcomes. Other audits include different sets of such concepts (Wiio, in Downs, 1994a; Roberts and O'Reilly, 1979). Such surveys may be administered regularly, with results reported back in aggregated form (such as by department), with open discussions of the implications of the results and how to improve the domains.

There are surveys designed specifically to assess internal user satisfaction with information systems (Ives et al., 1983) (including dimensions of satisfaction with IT staff and services, information product, vendor support, information product, and knowledge or involvement) and of task-oriented uses of Web interfaces (D'Ambra and Rice, 2001) (including dimensions of training, resources for interests, finding information, avoiding shopping costs, finding hard-to-locate information, entertainment, social influence, identity control, and use control).

External communication with users should also be conceptualized as part of the system design and implementation process. System designers need to identify and assess attitudes, needs, and expectations both as part of initial *user needs assessments* (Whyte et al., 1997) or even marketing, but also as ongoing formative evaluation, because the interpretation of any particular system, as well as the users' attitudes and needs, will change over time. A central principle of the customer relationship management literature is that "every contact point is a communication opportunity," so a broader conceptualization of a system would include interfaces and processes for fostering and maintaining ongoing interaction and feedback with users.

## 7.2 Communication of Innovations and Critical Mass

The subject of human factors generally involves the design or creation of some new technical artifact, or at least new features of a preexisting artifact. In this sense, human factors involves developing and diffusing innovations. However, typical conceptualization of system implementation ends once the innovation has entered the marketplace: that is, has left the design stage and has entered the production, marketing, and distribution phase. Occasionally, fitting the new system into its organizational setting (configuring, networking, adjusting) may also be considered part of this process. However, the diffusion of an innovation is a significantly more extensive process.

The diffusion of an innovation is the spread of a product, process, or idea perceived as new, through interpersonal and mediated communication channels, among the members of a social system, over time (Rogers, 1996). Innovations can be a new product or output, a new process or way of doing something, or a new idea or concept.

### 7.2.1 Diffusion Processes

Generally, the diffusion, or cumulative adoption, of an innovation over time follows an S curve: that is, growing slowly initially, then accumulating quickly, then flattening out as the maximum level of adoption is reached. Portions of this diffusion curve (i.e., standard deviations of the normal curve) can be characterized as types of adopters: innovators, early adopters, early majority, late majority, and laggards. Innovators and early adopters are usually distinguished by high levels of innovativeness and greater communication, education, and income, among other factors.

Diffusion and adoption can be measured in a variety of ways, such as number or percent of adopters at a certain time, number or percent of organizational units adopting, average duration of usage, number of innovation components adopted, number of units sold or implemented, level of system usage (such as number of log-ons, message sent, files stored, records processed), level of satisfaction, acceptance, diversity of planned uses, and number of new uses.

Crucial to diffusion of interactive communication innovations, such as an organizational intranet, is the achievement of a "critical mass," the number of adopters sufficient to foster sustained adoption beyond that point (Markus, 1987). This is because the value of the overall system grows exponentially as each additional user adopts, uses, and contributes to the system [the number of directed potential relations for  $N$  users is  $N(N - 1)$ , and the more contributions, the greater likelihood that one will be useful to another user], so that later adopters perceive and obtain much greater value than do early adopters. Further, with communication innovations, there are typically competing channels already in place, so that before critical mass is achieved, early adopters have to use multiple channels, while nonadopters, or late adopters, have to choose only one of the competing channels. Thus, it is important to provide early adopters with extra incentives, or to target clusters of early adopters who have special needs for, or who can gain particular benefits from, the new innovation. Unless critical mass is achieved early, the new communication channel will probably falter, and similar new systems may have to compete for users (Kraut et al., 1998).

Positive feedbacks, positive network externalities, and complementarities are benefits associated with innovations that accrue to later adopters rather than early adopters, benefits that increase the value of early versus later innovations, or services and other innovations that arise due to the success and features of an earlier innovation (Arthur, 1990). For example, the Microsoft Windows operating system has extensive positive externalities because, since it is the dominant

personal computer operating system, most other companies design their software applications for use under Windows. This, in turn, raises the value and market centrality of Windows. Thus, initial adoption patterns can heavily constrain or influence later diffusion, often institutionalizing initial innovations that are in fact less technologically or socially innovative or effective.

An intriguing extension of critical mass is the concept of adoption thresholds (Valente, 1995). The idea here is that each person has a (possibly variable) threshold for adopting a particular innovation. From a social and critical mass perspective, innovators have low thresholds: They may have sufficient resources, high innovativeness, unique relative advantages, and a low need for social influence. Later adopters have higher thresholds, but as more and more innovators adopt an innovation, the innovation becomes more commodified and there are greater social pressures to adopt, so these higher thresholds are more likely to be met. The implication here is that innovation implementers must be able to identify those with low initial thresholds and enable those to communicate soon after with those having slightly higher thresholds; also, different features need to be designed for earlier vs. later adopters, so as to lower thresholds more quickly.

Another time-based factor in the diffusion process is the "chasm" between early and later innovation design and adoption (Norman, 1998; Moore, 2002). Initial development of an innovation tends to be technology-driven, as widespread uses and critical mass have not yet been established. Here, developers attempt to design sufficient performance, features, and quality to satisfy early adopters, who are often willing to pay more (and become initial subscribers), and to tolerate poorer design, in return for new technological features and the status of innovators and early adopters. However, early and late majority adopters are not typically interested in the technological aspects but are more concerned about relative advantage, compatibility, and low complexity. Thus, the technology itself is not perceived as important; rather, usable devices, commodities, services, and content become more valued. The challenge for the developer and implementer, then, is to cross this chasm, knowing when to emphasize technology and when to emphasize the general marketplace.

There are several interim stages in a person's adoption decision process. These include knowledge or awareness of the innovation, persuasion (reactions to and evaluations of the innovation), decision (to obtain, purchase, try out), implementation (acquiring, adjusting, applying, including a "fair trial" period), and confirmation (including public display of the adoption and recommending the innovation to others). Within organizations, there are five major stages as well. These include agenda setting (a general definition of the initial rationale or problem statement, which may be more or less "rational" or well-informed), matching (alternative solutions are identified, evaluated, and compared to the agenda), redefining (the innovation's attributes are defined relative to the organization's needs, but

the alternative solutions may also lead to recasting the initial agenda), structuring and interconnecting (where elements of the current social system and/or the innovation are redesigned to integrate the innovation within appropriate procedures and processes, through both formal and informal negotiations and peer pressure), and routinization (where the innovation becomes a part of normal organizational operations). Initial understandings of a new system and its social applications may set an agenda that is then used as the criterion for design and implementation but which may, in fact, hinder ongoing design innovation and innovative uses (Johnson and Rice, 1987).

There are, of course, many other factors influencing the success, failure, or rate of diffusion of an organizational innovation. These include the justification for the initial agenda rationale; the geographic location and closeness of potential adopters; the complexity, size, and culture of the organization (decentralized, small organizations may be much better at initiating innovations, whereas centralized, large organizations may be more successful at implementing them); the personalities and power bases of the organizational actors; changes in political agendas, resources, and goals that affect the nature and evaluation of the innovation; different stakeholders becoming activated by different stages in the life cycle of the innovation; external organizational environments, including changing competitors, regulatory environments, and economic resources; and technological changes, rendering a current innovation incompatible or inappropriate (O'Callaghan, 1998). Because of these several stages in the individual and organizational adoption process, and the wide and complex range of factors affecting diffusion, an innovation may not be rejected initially but still may be discontinued at any stage of the diffusion process.

### 7.2.2 Innovation Attributes

Generally, potential adopters assess five main attributes of an innovation. Relative advantage is the extent to which the innovation provides greater benefits, and/or fewer costs, than the current product or process. *Compatibility* is the extent to which the innovation fits in with existing habits, norms, procedures, and technical standards. *Trialability* is the extent to which potential adopters can try out components of an innovation instead of the entire innovation, or can try out the innovation through pilot demonstrations or trial periods but decide to return to their prior conditions without great cost. *Complexity* is the extent to which potential adopters perceive the innovation as difficult to understand or use. Finally, *observability* or *communicability* is the extent to which potential adopters can observe or find out about the properties and benefits of the innovation. Every innovation has positive and negative aspects of each of these attributes.

Consider, for example, electronic mail. Clearly, a general critical mass of users has been achieved, especially within communities of certain online information services, but certain subgroups have low

overall levels of adoption so would not experience critical mass. E-mail has relative advantages over a face-to-face interaction because one can send the message at any time, regardless of where the other person is or how difficult it would be to meet with them. To many people, e-mail is still somewhat incompatible with traditional social norms such as sending holiday greetings but is highly compatible with other work and computer applications. With trial subscriptions or even free e-mail now offered, it is relatively inexpensive to try out electronic messaging, but one still has to have purchased a modem and communication software. Regardless of how simple advertisements make using e-mail appear, the various functions and interconnections with other applications still make e-mail fairly complex to understand and use. It is fairly easy to communicate the basic features, uses, and benefits of e-mail to others, but it might be hard to actually observe some of those benefits, or even one's own e-mail without taking the time and effort to check the e-mail system.

An innovation is not a fixed, static, objective entity. It may be adapted and reinvented. *Reinvention* is the degree to which an innovation is changed by the adopter(s) in the process of adoption and implementation, after its original development. A reinvention may involve a new use or application of an already adopted innovation or an alteration in the innovation to fit a current use. Reinventions may be categorized as to intentionality—planned (intentional) or vicarious (learning by other's mistakes)—and source—reactive (solving a problem generated by the innovation itself) or secondary (solving unintended consequences elsewhere in the organization or innovation due to the reinvention). The four levels of reinvention include unsuccessful adoption, successful adoption, local adaptation, and systemwide adaptation (Johnson and Rice, 1987).

### 7.2.3 Communication Channels

Communication channels also play an important role in diffusion. As the innovation is a new product, process, or idea, it must be discussed among developers and implementers and communicated to potential adopters in order for them to assess its attributes and decide whether to try out and eventually adopt it, and what the initial rationales might be. Very broadly speaking, mediated communication and interpersonal communication play complementary, but different roles. Electronic mass media channels such as television and radio are useful for raising awareness about the innovation but cannot provide much detail (except for specialty radio programs). They can provide images and brand name identification, helping the attributes of compatibility and observability. Print mass-media channels such as newspapers and magazines (and, to some extent, the Internet) are useful for explaining conceptual and technical details, helping out with the attributes of relative advantage and complexity. New media such as the Web can provide interesting mixtures of image, explanation, and demonstrations, thus also fostering trialability.

Interpersonal communication is especially important in changing opinions and reducing uncertainty about the innovation, as potential adopters turn to credible and important sources to provide firsthand experiences and legitimization of the new idea. Much innovation research shows the significant role that social influence, peer pressure, and social learning—all operating through potential adopters' communication networks and network roles—play in affecting the evaluation of the innovation's attributes, the adoption decision, and applications and reinvention. The *cosmopolite* is a member of a network who travels more, communicates and uses the media more, attends more conferences, and is generally more aware of the external environment than are other members. Thus, the cosmopolite is a valuable source to the social system for innovations. Within particular groups or organizational units, this role may be filled by a *technical gatekeeper*, who seeks out and brings into the group relevant facts and practices, freeing the rest of the group to focus on the group's task but also keeping it informed of innovative ideas. Within a social system, the *opinion leader* plays the valuable role of evaluating and legitimizing new ideas, especially normative ideas that fit in with the general social context of the group. The opinion leader must be fairly similar to the rest of the group in order to represent the central norms and values of the group, but tends to be just slightly more educated and experienced, and receives more communication, than the other members (Rogers, 1996). Different types of innovations or social norms may be regulated by different opinion leaders. For example, organizationally distributed task software, online games, and downloaded music would probably be discussed and evaluated by different (if somewhat overlapping) social groupings and opinion leaders. Thus, an important diffusion strategy is to identify the appropriate opinion leader for the type of innovation, communicate the relative advantage and compatibility of the innovation for that social system, and then provide incentives and communication channels for the opinion leader to diffuse the idea to other members.

An example application of combining the diffusion and network approaches to human factors is identifying the extent to which members' use of a new communication medium, such as the Internet, is due to (1) task/individual factors, (2) social/structural influences such as managers' and co-workers' opinions and use of the new medium, (3) the extent to which other resources and systems are connected through the medium (critical mass), and (4) the extent to which other valuable members (both inside and outside the organization) are connected. These kinds of studies have shown that adoption of a new system is influenced by one's co-workers (although also from managers when that person is a role model or opinion leader), is more likely if the medium is perceived as highly innovative or uncertain, if there is a potential critical mass of adopters, involves stronger network influences early on in the process while giving way to more individual-level influences such as task demands, perceived benefits, access, and ease of use (Rice et al.,

1990; Kraut et al., 1998), and is stimulated by greater network density and size (Papa and Papa, 1992).

## 8 IMPLICATIONS

In this chapter we have discussed six communication issues associated with human factors practice and research: messages, communication artifacts, communication characteristics of participants, group communication, communication networks and collaboration, and communication environments and innovation. The main theme is that communication is an interactive sense-making process constituted by messages and relationships among designers, users, and systems. Human factors must take into account the interpretive processes that produce shared meanings and collective action.

Engleke and Oliver's (2002) discussion of human factors activities in the design process provides a simple framework for suggesting how the communication issues discussed in this chapter pervade human factors issues. They identify five phases of activity, each of which is dependent on effective communication and intersubjective sense-making among designers, users, and machines. During *definitional activities* they suggest that designers must "solicit input from user focus groups to obtain preferences." *Designing device and human interface activities* need to "use metaphors that are familiar to the user." During the *implementation and testing phase* designers should "prepare to use interfaces sketches for early review and input by user groups." During the *refining stage* they must obtain "concrete feedback from users." Test activities include ensuring that "the full range of user expertise is integrated into test procedures." During the *user documentation phase*, the provision of "descriptive text and error messages" is critical.

Suggestions follow for how one or two example communication issues are embedded in each of these five design activity phases, highlighting some of the chapter's central concepts. Other communicative issues will clearly arise as human factors designers and researchers strive to improve the efficiency, effectiveness, quality, and safety of products and processes.

### Definitional Activities (Needs Assessment, Preferences)

- *Messages and sense-making.* Support sequences of interactions, and *metacommunication*, between designers and users, and among users, to make sense of what may be an unfamiliar feature or system concept.
- *Artifact as channel and content.* Find out how users may wish to use the system to communicate spontaneously with designers and implementers to maintain ongoing *interpretation* of the system and its possible applications; assess needs for possible changes in work and social interactions.
- *Communication differences.* Understand *cultural differences* in meanings and symbolism of

terms and practices, including methods of communicating about these (such as focus groups vs. individual interviews), and of selection, enactment, and retention sequences.

- *Group communication.* For potentially transformative systems, consider the *nominal* or *Delphi technique* to stimulate ideas without risk; identify group process gains and losses in project meetings.
- *Networks, collaboration.* Involve current and probable future stakeholders; identify current *expertise and knowledge networks*.
- *Communication environments and processes.* Identify what innovation attributes are especially salient for this problem, such as compatibility, and the extent of preexisting *critical mass*.

### Designing Device and Human Interface Activities

- *Messages and sense-making.* Identify *boundary objects* to support shared knowledge among different design professions.
- *Artifact as channel and content.* Build in support and *feedback* for designer communication, such as commentary, referent links, version archives, mobile participation, and *affordances*.
- *Communication differences.* Understand whether interface (such as searching vs. browsing) supports or biases different *message design logics*.
- *Group communication.* Project groups need to apply *social technologies* for both *task accomplishment* and *group maintenance*; *brainstorming* among designers and users.
- *Networks, collaboration.* Different media use, professional identities, *PERT* processes, and design preferences may create latent *cliques* and pockets of conflict; new systems are social as well as technical artifacts, so users must be involved in design and *assessment*; assess forms, *thresholds*, and simultaneity of *feedback* from the system to the operator.
- *Communication environments and processes.* Designer groups may wish to evaluate their own group communication processes during the project life cycle, such as *groupthink*.

### Implementation and Testing Activities

- *Messages and sense-making.* Some *strategic ambiguity* in marketed features and in outcome expectations may be helpful for early users to create their own sense of what is feasible.
- *Artifact as channel and content.* Provide *multiple channels* for users to discuss the new system among themselves and with implementers; seek out problems in task flow and work relations occasioned by the new system.

- *Communication differences.* Different content or relational communication, work roles, and organizational and national cultures may interpret or support implementation differently.
- *Group communication.* Offer group training and mentoring; identify group norms and attitudes that influence interpretation and use of the new system; obtain feedback in culturally sensitive ways.
- *Networks, collaboration.* Seed some systems in supportive networks with critical mass; promote knowledge sharing among early and late adopters.
- *Communication environments and processes.* Prevent early closure by initial innovation agenda; consider costs, benefits, and thresholds of groups of potential adopters.

### Refining Activities (Feedback)

- *Messages and sense-making.* Identify where retained understandings become rigid and out-of-date; continually assess how both relational and content communication from designers and implementers are interpreted by users and clients.
- *Artifact as channel and content.* Provide opportunities for interaction and commentary within modules and components, using different formats; assess whether a new system has negatively affected social and work networks, such as through problems of new access or expertise requirements.
- *Communication differences.* Some work roles or cultural members, or some organizational cultures, may suppress explicit criticism, so silence is not an indicator of no problems.
- *Group communication.* Reward emergent network roles about ways to improve the system continually; manage negotiations over system revisions.
- *Networks, collaboration.* Seek out and reward negative feedback in order to avoid closed social systems and dysfunctional systems; encourage user networks to develop.
- *Communication environments and processes.* Evaluate structuring processes beyond initial implementation; identify, evaluate, and diffuse reinventions and adaptations; foster knowledge sharing among different user groups.

### User and Error Documentation Activities

- *Messages and sense-making.* Technical and designer language will probably be highly ambiguous (both types 1 and 2) to users; consider any documentation or error messages as initial stages in sense-making interactions, so subject to ongoing editing, revision, reformatting, and updating.

- *Artifact as channel and content.* Avoid relying on a single channel or feature of a system to report or seek help about errors, as that may be the site or source of the error; build in detection of automation surprises.
- *Communication differences.* Technical and staff support should be aware of differences in their own message design logics and communication styles, and those of users, to avoid misinterpreting interactions.
- *Group communication.* New errors and explanations arise through system use over time, because of new users, interactions among system components, and changed work processes or roles, so maintain group interactions among designers and users.
- *Networks, collaboration.* Understand what network positions are the most helpful and knowledgeable, and what network positions others turn to for system help and guidance; they are often not the formally identified help positions.
- *Communication environments and processes.* Understand the social rationale for some kinds of errors, such as ironic or unfaithful adaptations of a system, or inadequate information load and low communication satisfaction.

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