A Systems Engineering Approach to Managing Communication in Globally Dispersed Teams

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Abstract

Globalization has caused firms to redefine regional strategies for distributed design and manufacturing into one of worldwide coordination and integration of resources in order to compete in the world market. This need to address customers and markets worldwide and to achieve a customer focus has led to restructuring of the organization, functions, activities and teams into globally dispersed entities. Globally dispersed teams are attractive because they promise benefits such as increased flexibility, responsiveness and lower costs factors critical to succeeding in this dynamic business environment. The major challenge facing product development and manufacturing organizations is to achieve high performing teams so that all the mentioned benefits can be realized.

Globally dispersed teams not only face the challenges of traditional teams; their situation is usually further aggravated by a lack of personal contact, culture and language differences as a result of dispersion in space and time. These factors make communication both within and outside the team boundaries difficult and can negatively impact team performance.

This thesis proposes that communication technology and multi-media capabilities can greatly enhance communication and organizational learning in the context of a globally dispersed team. Understanding which technologies and media solutions to apply in the face of culture, language and distance barriers in order to provide the most effective knowledge-sharing environment to support such a team is critical. By studying and analyzing the communication needs and media choices of dispersed product development teams and the impact of culture, language and distance differences on needs and choices, a method is proposed to design a communication environment and management strategies that reduce the effect of barriers and improve communications in globally dispersed teams.

To Valdis, my son, for all the inspiration and joy that he brings to my life.

– Viesturs

To my family, especially my grandmother Akua, and to Agnes and Kwame, my parents and my sisters Vida, Juliet and Lilly, whose prayers and support sustain me.

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– Gloria

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1.0 Introduction

Managing product development teams is one of the challenges organizations face as they strive to become a more customer-focused enterprise, while cutting development cost and cycle time. Over the past decade however, the need for globalization has added another layer of complexity to this challenge. Globalization has caused firms to redefine regional strategies for distributed design and manufacturing into one of worldwide coordination and integration of resources in order to compete in the world market. This need to address customers and markets worldwide has led to restructuring of the organization, functions, activities and teams into globally dispersed entities. As globally dispersed teams become more of the norm rather than the exception, organizations struggle to develop strategies to overcome the challenges they present.

Globally dispersed teams share the same basic needs of any team such as a clear mission, explicit statements of boundaries, roles and responsibilities, a variety of communication media choices and an environment that supports learning and growth (Kimball, 1997). It is important to note that globally dispersed teams not only face the challenges of traditional teams but their situation is further aggravated by culture differences, language differences and the dispersion in time and space. In spite of these difficulties, organizations have come to realize that the cost of not participating in geographically dispersed teams far outweighs the cost of managing these teams. In fact their very survival depends on how successful they are at working across time and space.

In most discussion of the problems with teams today, the topic invariably turns to the importance of communication both inside and outside the team boundaries. In the context of a global team consisting of members from distinct corporate and national cultures, efficient communication becomes even more relevant for project success. The communication environment must be aligned with the structure of the communication network, organizational needs and strategy, and must provide the context in which to overcome the cultural and language barriers that exist in a global environment.

Communication provides the framework for learning and knowledge creation. As such, effective communication is essential to the success of organizations.

> "The organizations that will truly excel in the future will be the organizations that discover how to tap people's commitment and capacity to learn at ALL levels in an organization." – Senge, 1990.

Advances in communication technology and multi-media capabilities can greatly enhance organizational learning in the context of any team. Nevertheless, technology alone does not guarantee the success of a globally dispersed team. Faced with added challenges arising from separation in space and time, a global virtual team must utilize multiple media that offer many pathways for interactions and the development of human relationships critical to building trust, a factor critical to the success of any team.

This thesis employs a system engineering approach to analyze communication within global teams. The method begins with first defining communication needs. Quantitative measurements of the needs and of the utility of media in satisfying these needs are performed using survey instruments. A conceptual framework and model for the communication processes is developed and subsequent analysis employs the Design Structure Matrix (DSM)

technique. Results of the analysis provide an understanding of how media solutions and the presence of culture and language barriers affect communication processes in global teams.

This paper begins with a review of the current literature on dispersed teams and factors that affect communication and performance. The main focus of the review will be on distance, modes of knowledge transfer, culture, language, communication structures and communication technologies. This review will highlight critical issues and key concerns with developing a communication environment to support global teams.

Data gathering techniques employed in this research include structured interviews and metaphor elicitation techniques. A survey instrument was developed to capture and analyze the communication needs and media choices of globally dispersed teams. Results from the survey quantify the relative importance of communication needs and the utility of different media to support these needs in the context of an environment to support knowledge creation. The survey measures the effect of barriers such as culture, language and distance that exist in the global teams.

Using numerical DSM (NDSM) methods, a process for analyzing the communication flow within globally dispersed teams is developed. Typical product development task-based DSM analysis defines the requirements for team interactions based on a priori knowledge of the product architecture, the task sequence and the systems engineering organization. With the communication NDSM model, a more efficient structure of communication as defined by traditional DSM methods can be deployed encompassing the selection of appropriate media and the specification of optimum team interactions in the context of required collaboration among team members.

The NDSM is extended using a special form of the Work Transformation Matrix (WTM). Typical WTM applications involve task scheduling and concern the probability that a particular task will cause subsequent iteration once it is performed. It uses a measure of the probability of rework present in a feed-forward/feed-back loop. The reason for repeating tasks is often associated with the completeness of information in the communication flow. In this research, the WTM is applied to communication media utilities in the presence of culture, language and distance. Media utility based probabilities that include the effect of barriers are defined and used to determine the overall effect on the time it takes a global team to make decisions and reach consensus.

2.0 Literature Review

There are many factors that impact effective communication in teams, many of which have been examined in detail in prior research. Predominant issues in nearly every discussion of communication effectiveness in global teams are related to culture, distance and language. Research on communication in teams has attributed the success of product development teams to effective communication between upstream and down stream activities (Clark and Fujimoto, 1991). Ineffective technical communication can negatively impact the performance of a team and must be improved in areas where it affects project performance. (Wheelwright and Clark, 1992)

2.1 Distance

Much of the previous research on communication in dispersed teams has focused on the effects of factors such as distance and time zones, organizational and task structure on technical communication between teams (Sosa et al., 2000; Morelli et al., 1995; Griffin and Hauser, 1992; Allen, 1977).

A common theme that has evolved from these studies is that in spite of the abundance of media choices teams have today to fulfill their communication needs; there is still a need for personal interaction. Geber (1995) believes that human factors or the people side of the equation are key to the success of a team. There is more likelihood of success when these people issues are addressed at the beginning and continuously through a team's existence. This is especially relevant to long-term projects or in the case where team members believe

they might collaborate on future projects. His study goes on to provide empirical evidence of the importance of personal contact.

According to De Meyer (1991) "periodic face-to-face contact seems necessary to maintain confidence at a level high enough to promote effective team work." Allen (1977) argues that efficient communication within engineering networks is best achieved through face-to-face contact and that the intense exchange of information that characterizes R&D environments is greatly facilitated when individuals have the ability to control the speed with which information is offered and provide immediate feedback.

The conclusion here is that some face-to-face contact is necessary to build trust, a necessary component of effective teamwork. Jarvenpaa, Knoll and Liedner (1996) maintain that "...the higher the level of trust for a team, the greater cohesiveness, satisfaction and perceived effectiveness". It can be argued that trust is a critical success factor for any team, dispersed or collocated, however the question that arises with a globally dispersed team is how this trust can be established with little or no face-to-face interaction. In other words, can trust be established virtually? Jarvenpaa, Knoll and Liedner (1996) argue that this is possible; however, trust built virtually is fragile and needs to be reinforced by performance in order not to erode.

Many proposed remedies for overcoming the effects of distance have involved the use of communication technologies and media. In fact, much of the study of media in the context of global teams has been related to overcoming the issues associated with separation in space and time. However, the need for personal interaction to build relationships extends beyond the capabilities of communication media that leverage many of the existing technologies

available for effective communication over distances. Also the advantage of one medium over another for distance communication does not necessarily correspond with the capability to compensate for barriers associated with language and culture.

Allen's (1977) study of communication in R&D organizations indicates that the probability of technical communication between team members decreases with distance. This finding has been extensively corroborated by other research (Keller and Holland (1983); De Meyer and Mizushima (1989); Jaffe et al. (1993); Pinto et al. (1993); Van den Bulte and Moenaert (1998)). Sosa (2000) found that the frequency of technical communication reduced with distance across all communication media employed, however the magnitude of this effect varied with different media. Face-to-face frequencies decayed faster than telephone and email frequencies. The presence of strong organizational bonds and team interdependence served to mitigate the negative effects of distance.

2.2 Culture - Communication and Product Development Teams

Hofstede (1980) used the term culture to describe entire societies and defined culture as "Collective programming of the mind", the way that " a group of people solves problems and reconciles dilemmas".

Culture can simultaneously be a source of great difficulty and competitive advantage to a globally dispersed team. Since culture can impact a global team in several ways, from meeting participation to the use of communication technology, an organization that can overcome the challenges of culture in a globally dispersed team and effectively leverages these differences to create synergies usually outperform teams of a more homogenous nature.

Hofstede (1980) argues that national culture should be viewed as an organizational asset and should be fostered. Critical to the success of a team is the consideration of these factors and designing a suitable environment to facilitate team collaboration. There are three categories of culture that members of globally dispersed teams bring to the team experience. These categories include organizational, functional and national.

2.2.1 Organizational Culture

Schein (1992) defines organizational culture as "a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think and feel in relation to those problems."

Various levels of culture range from the very tangible, that which can be seen and felt to the highly intangible embedded, unconscious basic assumptions. Basic assumptions can be very difficult to identify and may include things like the perception of the importance of time (schedules and time tables) and theories about human nature. Basic assumptions are so taken for granted that people who do not share them are sometimes viewed as stupid or crazy.

Schein (1992) analyzes culture on three levels: artifacts, espoused values and basic underlying assumptions. Figure 2.1 below details this analysis.

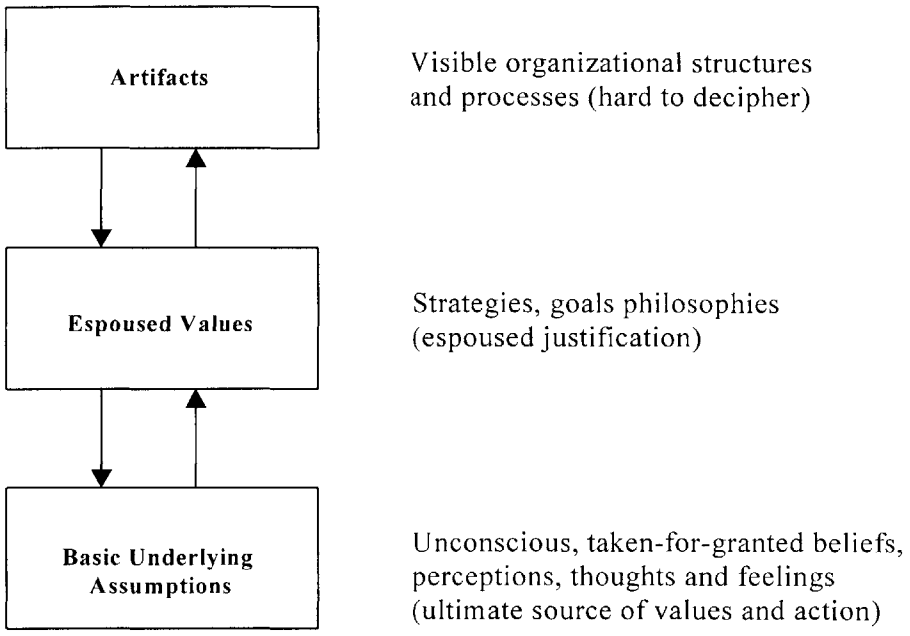

Figure 2.1 Levels of Culture

There should be little impact of organizational culture on globally dispersed teams derived from the same organization since they presumably share this culture. However, if there exists a large disparity or discontinuity in the average length of service of individuals within an organization, organizational culture can have a significant impact on the behavior of the group as a whole. Organizational cultural differences are also often encountered in organizations that are the product of recent mergers or acquisitions. When organizational culture is similar, differences due to functional and national culture can still have significant implications.

2.2.2 Functional Culture

Functional culture is culture based on the functional groups of an organization such as engineering, marketing and sales. Functional culture is usually classified as a sub culture of organizational culture and is derived from shared educational experiences, technology and occupational culture of a function. Although individuals in functional groups might share the basic culture of the organization they also share certain additional basic assumptions because of this association with their occupational community (Van Maanen and Barley, 1984). It is plausible that an individual might identify more with a functional culture more than the organizational culture.

Communication difficulties between functional groups are frequent and hard to resolve even in co-located situations. This situation is very likely to be even more problematic when there are culture and language differences as well as dispersion in time and space. Key to resolving issues related to differences in functional culture is to employ artifacts and espoused values that reinforce the team.

2.2.3 National Culture

National culture is the most embedded form of cultural distinction and is reinforced from early childhood. National culture is the highest level of culture and is usually the most obvious. There are six dimensions to national culture namely, power distance, uncertainty avoidance, individualism-collectivism, masculinity-femininity, long-term-short-term and context. Prior research (Hofstede, 1980) to identify and quantify national culture and focused on further elaboration of the six dimensions as discussed below.

Power Distance

The basic issue here is the concept of human inequality or in the case of organizations, the concentration of authority. This dimension deals with the extent with which less influential members accept or expect power to be equally distributed. In large power distance cultures, people in high status positions receive asymmetric respect and priority treatment from subordinates. Managers and supervisors are "superior" or more knowledgeable by virtue of their position or title. In low power distance cultures, supervisors and subordinates strive to achieve a more equal relationship. Subordinates expect to be recognized and respected for their personal traits and give little deference to people merely due to their higher status positions. Supervisors and managers act more as consultants rather than authoritarians. Problems arise when supervisors and subordinates are at opposite ends of the spectrum. For example a large power distance supervisor might expect subordinates to give more deference whereas the low power distance subordinates expect more personal respect from the supervisor.

Uncertainty Avoidance

This dimension deals with the degree of tolerance of ambiguity, or the degree with which members accept or expect tasks to be structured. High uncertainty avoidance cultures prefer more detailed and predictable plans or processes. There is a low tolerance for ambiguity, which could lead to anxiety. Low uncertainty avoidance cultures are more tolerant of ambiguity and can function well with minimal structure to tasks or definition of roles and responsibilities.

Individualism-Collectivism

The preference members have to act individually or as a group. Individualism emphasizes the individual's identity over the group identity. There is a strong preference for individual rights and a reduced sense of obligation to the group. Collectivism emphasizes group identity over individual identity. Group obligations take precedence over individual rights and desires. Implications for communication might include the strong assertion of personal opinions from members of individualistic cultures whereas members from collectivism cultures tend to present collective ideas and opinions.

Masculinity-Femininity

This dimension indicates the degree to which "masculine" values are given priority over "feminine" values. "Masculine" oriented cultures are concerned with financial success, material possessions and status; there is a belief that all contributions to team performance can be objectively measured. "Feminine" cultures care more about nurturing, cooperation and sharing; there is a belief that contributions to team performance can be subjectively measured.

Long-term-Short-term

This dimension can be defined as the degree of family orientation, parsimony, virtuous behavior and acquisition of knowledge and skills. Long-term oriented cultures are more concerned with the future and will use frugality and persistence to achieve long-term success. There is more concern for acquiring skills and knowledge. Short-term cultures are motivated by immediate physical or financial success. There is a need for immediate reinforcement otherwise become impatient.

Context

There are two categories here, high and low. This is the amount of extra information and intuition required for decision-making versus facts. In low context cultures communication emphasizes expression through explicit verbal messages whereas in high context communication involves the conveyance of meaning or intention through context (social roles, positions) and nonverbal channels (pauses, intonations and silences) of verbal communication (Hall, 1976). In low context communication, there is an expectation of a clear and concise message that can be understood easily; in high context communications, the listener is expected to correctly read "between the lines" and to infer the implicit intent of the message also by reading nonverbal cues.

2.3 Patterns and Structure in Communication

In a globally dispersed team context, where personal contact is lacking, mechanisms must be developed to "replace or support individual, face-to-face communication" (De Meyer, 1991). De Meyer investigated the communication management practices of fourteen multinational corporations involved in globally dispersed teams and sorted their practices to enhance communication into six categories:

- Efforts to increase socialization in order to enhance communication and information exchange

- Implementation of rules and procedures in order to increase formal communication

- Creation of boundary-spanning roles – assigning individuals as gatekeepers to facilitate communication flow

- Creation of a centralized office responsible for managing communication

- Development of a network organization

- Replacement of face-to-face communication by electronic systems

Of the practices observed by De Meyer the creation of a centralized office for communication is of particular interest. Several approaches toward global interaction involve the set up of various communication patterns to facilitate teamwork. Two major categories of communication patterns emerge: Centralized and Networked.

Centralized

The centralized pattern of communication is characterized by the assignment of gatekeepers to regulate communication flow. In this setup, there is tight control of communication flow, with all communication going through a central control. In a globally dispersed team with cultural and language differences, this provides an opportunity to filter, translate, sort and organize information into a more user friendly way for the recipient. Other reasons for using a centralized structure are resource constraints or a poor communication infrastructure.

Smith (1966) studied the effects of communication patterns on group performance to determine the best performance. He experimented with four patterns of communication

representing extremes in centrality: "Circle" (least centralized), "Chain", "Y" and "Hub and Spokes"(most centralized).

In the study, four groups of five people were formed to perform a task that required the simple collection of data. Each group was assigned a pattern of communication and asked to use two-way written communication so that communication flow could be tracked easily. A node represented each participant.

Circle

In this scenario, communication flows in a circular pattern until a particular node has received a desired response or sufficient information for further processing of work. There is no consistent operational organization and nodes could not clearly identify a leader.

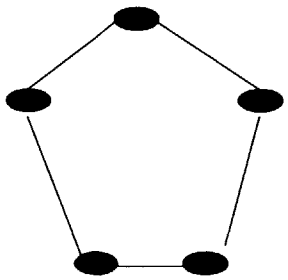

Figure 2.2: Circle Pattern for Communication

Chain

In this case, information is funneled from both ends to the node at the top. When information flow, such as a desired answer or response, has reached the top node, it is disseminated back down to the lower nodes. In some cases, lower nodes derived the answer but still funneled it to the top node to be distributed to the rest of the network. The organization such a network is slow to emerge but remained consistent after emerging.

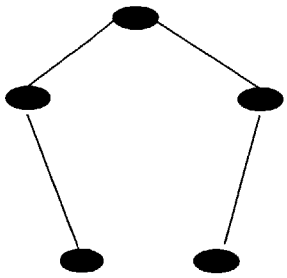

Figure 2.3: Chain Pattern for Communication

"Y"

In the "Y" configuration, the center most position was given complete decision-making authority. All other nodes served as transmitters of information and answers. It is possible that not all nodes are utilized especially when they occur in series. Smith found that the organization emerged more rapidly than in the chain configuration and was more stable.

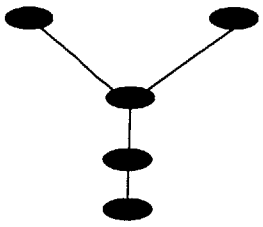

Figure 2.4: "Y" Pattern for Communication

Hub and Spokes

In this case, all nodes on the peripherals can send information to the center where a decision is made and then the result is sent out to all nodes simultaneously. The organization evolved rapidly and remained in stable. A leader (center) was clearly identified by all nodes.

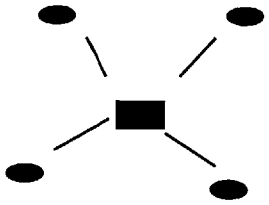

Figure 2.5: Hub and Spokes Pattern for Communication

Network

The network communication structure is another alternative for globally dispersed teams. In this pattern, there are no restrictions on communication flow and all nodes are free to communicate directly with other nodes. With no central controlling entity this approach requires willingness from management to give up tight control of information flow in order to be effective. It also requires that the organization support the development of these networks through travel, job rotation and investment in the appropriate communications infrastructure.

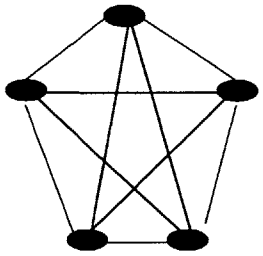

Figure 2.6: Network Pattern for Communication

While it would seem that management would in principle prefer centralizing responsibility for communications because it translates into easier monitoring and control, as opposed to informal networks, the latter enables gains in efficiency, by eliminating delays as information flows freely between end users. The tradeoff between speed and control should be critically

analyzed before a communication structure is selected. In some cases a hybrid structure may provide the best answer.

2.4 Technology

While advances in technology have made global teaming a reality, organizations that have relied on technology alone to improve the performance of their globally dispersed teams have typically been disappointed. The heavy investments in multi-million dollar state of the art technologies have failed to improve team performance. This is because of the failure of the teams to use technology in more effective ways. While technology can help an organization exploit more opportunities, it cannot remove the challenges faced by global teams.

2.4.1 Creating a Shared Space

One of the goals in the selection of technology should be its suitability for creating a shared space (Schrage, 1995). For collocated teams shared space can take various forms including meeting rooms and bulletin boards. In a dispersed team creating a shared space is more challenging and could take the form of an electronic live-board, an email distribution list or a virtual team room (Benson-Armer and Hsieh, 1997). A shared space is created only when teams collaboratively employ communication media to actually discuss and debate ideas or for other creative purposes. The creation of a shared space not only involves the use of technology but also the development of procedures and protocols to support the use of the technologies.

There are a variety of communication technologies that can be used to support globally dispersed teams. Duarte and Snyder (1999) used the term groupware to describe the

categories of electronic systems that integrate hardware and software to facilitate communication in dispersed teams. Video conferencing and email are examples of the most widely used groupware used today. As the use of the Internet and data transfer capacity (bandwidth) increases, a new era of more practical and user-friendly groupware is emerging.

There are two general modes of interaction: synchronous (real-time interaction) and asynchronous (delayed interaction). An additional dimension of time can be added to these modes to produce grouping as illustrated in Figure 2.7.

		Place	
		Same	**Different**
Time	**Synchronous**	**Same Place – Co-located** **Same Time - Synchronous** Face-to-Face meetings Computer -supported meetings	**Different Place - Distributed** **Same Time – Synchronous** Video conferencing Audio conferencing Electronic meeting systems (EMS) Desktop and real-time data conferencing
	Asynchronous	**Same Place – Co-located** **Different Time - Asynchronous** Library "War" room	**Different Place - Distributed** **Different Time – Asynchronous** E-mail Voicemail Web pages and bulletin boards Database sharing and conferencing Group calendars and schedules

Figure 2.7: Modes of Interaction

Adapted from Duarte and Snyder, 1999

2.4.2 Properties of Media

The capacity of media to support different contexts of communication is based in the properties and nature of specific media themselves. According to McLuhan (1964), the content of any medium is always another medium. For example, the content of a movie is the novel. Similarly, the content of a novel is speech. As a consequence, no medium exists or has significance in and of itself, but always in relation to and interaction with other media. McLuhan's encapsulates this notion in his celebrated quote: "The medium is the message."

McLuhan studied and compared the properties of the traditional media of print with what he considered to be the electronic, or new media of what he referred to as the Information Age. Traditional media are associated with text and print that appeal primarily to the visual sense, are characterized by classification and defined syntax. Such media present information in a sequential, continuous manner and are generally construed as soliloquy. The media of print is the realm of the specialized individual, in that it often is of limited relevancy due to the intended audience of specific jargon.

New media, instead of being character or text based, rely on symbolism to convey messages. Such media are tactile and appeal to multiple senses. Rather than a sequential, cause and effect interpretation, messages in such media are the subject of pattern recognition and are often discontinuous. New media are also less focused to the needs of the individual specialist, but are designed to appeal to the sense of what McLuhan coined as the "global village."

With the exception of text-based email, much of electronic media shares the properties associated with new media. Such media can generate increased awareness of the group, which is an important consideration of global team technologies. Furthermore, electronic media tend to favor the spoken word and imagery over the specialist, literary style. The profound implications are a new culture based in verbal language and symbolism in the corporate environment. As such, new media may also offer increased potential to harness and disseminate tacit knowledge.

2.4.3 Group Processes and Conversations

One important consideration for selecting a technology for the mode of communication is the purpose of the group process. Kimball (1997) defines four basic processes for groups: relationship building, divergent conversation, convergent conversation and sustaining action.

Relationship Building

Kimball defines relationship building is the process of "lubricating and sustaining the ability to be productive and constructive." Relationship building is important to groups in that it helps develop camaraderie and creates a harmonious environment for groups to work in.

Divergent Conversation

Divergent conversation allows groups to generate creative, high quality and an exhaustive list of ideas for a particular question, issue, or effort. As such, divergent conversation occurs when it is necessary to getting the thoughts and ideas of team members out in the open. Processes such as brainstorming characterize this type of communication.

Convergent Conversations

Convergent conversation is the process of distilling and summarizing thoughts, ideas and other information generated to determine what is important. This process also includes negotiation and decision-making. Convergent conversation allows the group to organize and prioritize their thinking. It creates a shared meeting that prepares the group for taking collective action.

Sustaining Action

Once ideas have been debated and decisions have been made, it is important for the team to maintain continuous communication in order to support implementation and ensure performance over time. The purpose of sustaining action is to effectively implement ideas and decisions the team has agreed on. Roles and responsibilities are assigned and performance is tracked and measured.

All these modes of interactions and technologies support group processes to some extent. For example there is a notion among most people that face-to-face meetings (same time, same place) are best for building relationships and trust. In cases involving divergent ideas and high conflict, face-to-face alone might not be appropriate since some members might not feel comfortable expressing disagreement openly. In this situation supplementing face-to-face with certain technology that allows for anonymous input of data might allow for increased participation and quicker resolution of conflict.

The Table 2.1 summarizes the effectiveness of certain modes of interaction for group process.

Table 2.1: Effectiveness of Modes of Interaction in Supporting Group Processes

Adapted from Kimball, 1997

Mode of Communication	Group Process: Relationship Building	Group Process: Divergent Conversation	Group Process: Convergent Conversation	Group Process: Sustaining Action
Same Time Same Place (With technology)	Allows for the reading of body language etc. Preferred way to build trust and relationships Allows for the anonymous input of data which can help resolve difficult issues	Can build on others' ideas. More opportunities for creativity. Can generate input rapidly because participants can enter data simultaneously	Various tools can be used to rank divergent ideas Pressure to reach decisions quickly Allows the collective thinking of the group to be quickly accessed	Very powerful when members need to make commitments to take action. Provides full documentation of what was discussed and agreed upon in a meeting.
Same Time Different Place	Media that allows members to be seen or heard create feeling of togetherness Provides common reference points	Allows for data to be gather from a larger sample of people	The choices can be presented several formats. Good way to get clarification about issues. A lot of Q&A possible in a short time	Technologies provide check in mechanism. Same-time quality allows creation of targets and deadlines.
Different Time Different Place	Web-based interaction allows for more personalization (pictures, bios etc) allowing members to identify with each other	Geography and other logistical constraints do not limit people contributing ideas Allows more time to think about questions or ideas	People feel that they have power over when and how to participate. More open to collaboration when they are not forced to decide an issue within a face-to-face meeting. Time difference allows the collection of additional data	Different time/different place media can create a permanent project record and reference. New members can be brought up to speed quickly.

2.4.4 Considerations for Selecting Technologies

Several important considerations arise when selecting technologies have been identified. These include the capabilities of specific media for supporting different modes of interaction such as information sharing, brainstorming, decision-making and other collaborative work processes. A general correspondence exists between group processes as discussed above (Kimball, 1997) and these modes of interaction. For example, divergent conversation and brainstorming are essentially the same processes, just as decision-making is part of the convergent communication process. Sustaining action processes include interaction modes associated with collaborative work. Relationship building, however, is a much more profound process that evolves as a result of the trust generated from reinforcing shared experiences. This is a dynamic process that extends across all the modes of interaction and occurs over time. Failure or unresolved conflicts in any interaction mode can be disruptive to relationship building processes. Therefore, it is critical that appropriate technology be selected to provide the desired support for all interaction modes.

While the general correspondence between Kimball's communication processes and the modes of interaction do exist, the level of interaction that any meeting demands actually lies on a continuous scale of varying degrees of interaction. Since meetings are dynamic events, they can quickly shift from one communication process to another. This is especially true of projects at an early stage, where many rapid iterations of information sharing, brainstorming, decision-making and other forms of collaboration can occur. Therefore, face-to-face meetings can be beneficial especially at the beginning of a project.

Table 2.2 summarizes the interaction continuum and the relevant communication media that best support different degrees of interaction.

Table 2.2: Meeting –Interaction Continuum

Information Sharing	Brainstorming and Decision Making	Collaborative Work
Low Interaction	Moderate Interaction	High Interaction
Voice mail Email	Electronic bulletin board Chat rooms Video conference Audio conference Real-time data conference	Real-time data conference with audio/video and text Whiteboards with audio/video link EMS with audio/video and text and graphic support Collaborative writing tools with audio/video links

Duarte and Synder, 1999

Often it is possible to categorize more routine meetings that occur at defined stages of a project according to a specific task that is dominated by a given interaction mode. In such situations, there should be a clear strategy for matching technology to the task. Experience levels with using particular technologies and its availability, as well as time constraints associated with completing the task are important factors in deciding which medium to use. Other important considerations include the following:

- Information richness and social presence are not always necessary to perform a task. For example, standard review meetings need not be face to face.

- New technologies are not always the best choice. A good audio conference is always preferable to a videoconference with poor picture quality etc.

- Technologies should be selected based on team experience level and assigned tasks.

  There is no standard communication tool that will work well for all occasions.

Table 2.3 summarizes the effectiveness of various media for different interactions.

Table 2.3: Meeting –Selection Matrix

		Purpose of Meeting		
Type of Technology	Information Sharing	Discussion and Brainstorming	Collaborative Decision Making	Collaborative Product Production
Voice mail	Somewhat effective	Not effective	Not effective	Not effective
Audio conference	Effective	Somewhat effective	Somewhat effective	Not effective
Email	Effective	Somewhat effective	Not effective	Not effective
Bulletin board	Somewhat effective	Somewhat effective	Not effective	Not effective
Real-time data conference (no audio/video and text)	Effective	Somewhat effective	Not effective	Somewhat effective
Video conference (No shared document)	Effective	Somewhat effective	Effective	Not effective
Real-time data conference with audio/video and text	Effective	Effective	Effective	Effective
EMS with audio/video and text and graphic support	Effective	Highly effective	Highly effective	Effective
Collaborative writing with audio/video links	Effective	Effective	Somewhat effective	Highly effective

Duarte and Synder, 1999

Effect of different cultural backgrounds of team members should also be considered. Different media channels may be required to accommodate a mix of cultural factors.

Table 2.4 shows compares some of the relevant issues associated with the factors associated with national culture as discussed in Section 2.2.3.

Table 2.4: Technology and Culture

Cultural Factor	Technological Considerations
Power Distance	• Asynchronous technologies. • Allow anonymous input
Uncertainty Avoidance	• Slower adopters of technology • Prefer technologies that produce permanent records
Individualism-Collectivism	• Highly collectivistic cultures may prefer face-to-face
Masculinity-Femininity	• More "feminine" oriented cultures use technology in a nurturing way at team start up.
Context	High Context: • Information rich technologies • Prefer technologies that offer opportunities for social presence, might resist low social presence technologies for communicating with people they have not met. Low Context: • Prefer asynchronous technologies

Adapted from Kimball, 1997

However, with regard to the selection of technology-based media, one should keep in mind the consequences as presaged by McLuhan:

"We become what we behold. We shape our tools and afterwards our tools shape us."

2.5 Language

Language is often considered to be an obvious manifestation of culture, creating the perception that language differences are synonymous with cultural differences. According to UNESCO (1994), there are more than 5,000 different languages, with an even larger number of dialects spoken around the world. In this paper, we distinguish between the culture and language in order to treat them separately. Acquiring the language skills of a different culture is valuable in understanding the dynamics of that culture and helps build relationships with members of other cultures, thus facilitating cultural adjustments especially among expatriates (Mendenhall & Oddou, 1985). It is commonly believed that to be competent in cross-cultural situations, specific knowledge of the host language in addition to an appreciation of cultural differences is essential (Copeland & Griggs, 1985; Harris & Moran, 1991). It should however be noted that willingness and confidence in using the host language has greater influence than the actual level of fluency (Mendenhall & Oddou, 1985).

There are several methods for people of different languages to communicate with each other. These included one-way or two-way bilingualism, multilingualism, passive bilingualism and the use of lingua francas.

One-way Bilingualism

One-way bilingualism is the case where only one of two groups that speak different languages learns the language of the other. The group that usually learns to speak the other

language is typically economically dependent on the other, allowing the language of the more powerful group to take precedence over theirs.

Two-way Bilingualism

Two-way bilingualism occurs when two groups that speak different languages learn each other's language to some extent. This is active two-way bilingualism. There is typically a balance of power between the two groups in this case.

Passive Bilingualism

Passive Bilingualism is the case where groups that speak different languages learn to understand but not speak the others' language. This is possible in situations where the languages are closely related and enough understanding can be achieved through both verbal and non-verbal channels.

Lingua Franca

In the case where communication occurs in a language not native to any of the parties, the spoken language is known as a lingua franca. An example of the use of a lingua franca is when a Japanese and German communicate in English. There are several reasons for the adoption of a lingua franca some of which are the perception of prestige or higher status due to cultural or political supremacy, or the facilitation of trading relations. The use of lingua franca is common to global teams.

Findings from research associated with the effect of language differences on communication in global teams indicate that language differences do impact teams in several ways. For example for interactions conducted in English, it is highly probable that non-native speakers

might need additional time for translate and decipher information which can significantly reduce their level of participation or slow the communication process down. Sosa (2000) found that there is a negative correlation between language differences and face-to-face interactions, indicating that in the presence of language differences there is a preference for written asynchronous media such as email instead of verbal synchronous media such as face-to-face and telephone.

2.6 Four Modes of Knowledge Transfer in Communication

The ultimate goal of communication is to transfer knowledge. A useful framework for understanding how knowledge transfer takes place was been proposed (Nonaka, 1996). In Nonaka's model, as shown in Figure 2.8, knowledge is considered to exist in one of two forms as either Tacit or Explicit. Tacit Knowledge exists as the result of personal experience and memory. It requires context in order to be explained and communicated.

Explicit Knowledge is recorded in formal syntax or systemic language. Once codified, it can be readily communicated. No single form or process exists that accommodates all forms of knowledge transfer between individuals and among teams. In order for communication to be effective, it must facilitate all four mode of knowledge transfer described in the chart below.

Technology cannot be merely positioned as an alternative for human interaction in the process of transferring knowledge. This is particularly true in the case of tacit-tacit knowledge. Socialization cannot occur if people do not interact. Communication media offer different levels of satisfaction of the needs of communication.

		To	
		Tacit Knowledge	**Explicit Knowledge**
From	**Tacit Knowledge**	Socialization	Externalization
	Explicit Knowledge	Internalization	Combination

Figure 2.8: Four Modes of Knowledge Transfer (Nonaka, 1996)

Note that the notation used in this study and discussion of results uses the following convention,

T2E = Tacit-to-Explicit (Externalization – Tacit Knowledge becomes a Metaphor)
T2T = Tacit-to-Tacit (Socialization – Apprenticeship, On-the-Job Training)
E2T = Explicit-to-Tacit (Internalization – Learning by Doing)
E2E = Explicit-to-Explicit (Combination – Different Sources of Explicit Knowledge)

The Nonaka theory of knowledge creation is used to categorize communication modes that will be used to study the effectiveness of media in specific contexts of communication and knowledge transfer. This theory is used as a framework for developing a survey to develop a quantitative analysis of media in Section 3.3.

3.0 Interviews and Survey Development

This chapter describes methods of collecting data and includes interviews conducted with a sample of Sponsor Company employees and structured interviews using the ZMET method. First, a group of subjects from the Sponsor Company with experience in a variety of global teams were interviewed using a set of questions designed to gain an understanding of the communication needs, language and cultural issues and overall best practices that promotes global team effectiveness. The survey and its findings are discussed in Section 3.1. Subsequent ZMET interviews were conducted with a group of subjects recruited from outside the Sponsor Company that also had experiences in working with geographically dispersed teams. The ZMET interview is a structured Voice of the Customer methodology designed to better extract the needs associated with a product or topic, which in our case was the communication process. The ZMET methodology and its application in this study are discussed in Section 3.2. Results from both interview process were used to define a hierarchical set of needs that was a basis for developing survey questions. Section 3.3 compares the findings of the ZMET process with the comments and statements observed within the surveyed group of Sponsor Company subjects. Comparison of the derived needs from the ZMET approach matched the needs espoused by the Sponsor Company group. Experience in using both methods during the course of this study demonstrates that the structured interview approach using the ZMET methodology produced a much better understanding of communication needs and associations among such needs than would have been possible using the data collected from the interviews performed with the Sponsor Company population alone.

3.1 Sponsor Company Communication Interviews

Technology is constantly growing while giving users many different options to communicate and collaborate. Choices range from face-to-face conversation to paper letters, telephones, cellular phones, pagers, and e-mail among others. Communication is an integral element supporting global team processes. Therefore, it is useful to know how communication impacts team processes, what drives communication choices and what may be lacking in the tools that are available today. To gain an understanding of such issues, interviews were conducted with a sample of subjects from the Sponsor Company that have experience in working with global teams.

3.1.1 Interview Structure

The interview was structured using the questionnaire included in Appendix I. This questionnaire is divided into groups of questions designed to gain an understanding of global team processes and the impact of selecting certain communication media. The outline of the survey is as follows:

1. General Team Data – In this part of the interview, subjects were asked to identify their global team, the size of the team, the level of dispersion within the team and their specific responsibilities on the team.

2. Team Meetings – This section asks questions regarding how team meetings are conducted, what protocols or formats are used to facilitate the meetings and what difficulties arise in the course of conducting such meetings.

3. Communication Media – Questions were asked relative to the communication media employed by the team and the level of difficulty experienced with the use of different media. Questions focused on the use of email and the concerns associated with the ability of email to support communication in the team. An additional question was asked to identify occurrences requiring direct face-to-face meetings where other media were inadequate.

4. Organizational Learning – This section of the interview was concerned with how the subjects located information needed to perform their role on the team and asks them to describe instances wherein they found it difficult to locate or otherwise obtain the information they needed.

5. Cultural Issues – Subjects were asked to identify and describe the extent to which cultural and language barriers exist within the global teams.

6. Technology – This section of the interview focused on the communication technologies used by the team, how such technologies are used and describes the shortcomings of currently available communication technology.

In concluding the interview, follow-up questions were asked to discuss any additional questions that the subjects would like to have been asked as part of the survey. Using the questionnaire, participants in global teams were interviewed in depth to develop a qualitative assessment of the fundamental needs of communication. Combined with the ZMET interviews, these needs were then further structured and developed into a survey useful for

developing a quantitative understanding of the relative importance of the needs and how they relate to media in the context of global team processes and organizational learning.

3.1.2 Discussion of Interview Findings

Using the outline above, the responses from each section of the interview are discussed in detail.

General Team Data

A total of eight subjects were interviewed representing four separate Sponsor Company global teams. Team sizes ranged from as few as eight up to 25 members. While the subjects themselves were primarily based in Europe and North America, collectively, the teams they represented encompassed a level of dispersion that extended to all major continents and locations where the Sponsor Company conducts business. The subjects also ranged in position and level of responsibility from product design engineers to director-level managers.

Team Meetings

Most global team meetings occurred on a monthly or bi-weekly basis. Practices related to the facilitation of meetings and support of team processes was varied, but included basic protocols such as maintaining and keeping with an agenda. Other practices used to reinforce team processes included the distribution or relevant documents to all sites prior to the meeting using email or the company intranet. Teleconference (voice) was the primary mode of communication, while videoconferences were scheduled much less frequently. Face-to-face meetings were limited to annual or semi-annual events.

Some of the difficulties that were observed in using teleconferences were the lack of feedback and participation by remote sites. In some cases participation was frustrated by a relatively high turnover rate in team membership. During the course of the meetings, participation in conversations within the meeting tended to be dominated by the site chairing the team interaction. Participation was perceived as being particularly low with regard to team members located in South America and Mexico. Example quotes from subjects involved with different teams reflect such sentiments:

> "...Most conversation (60%) occurs within our own conference room, 30% - England, 10% - Mexico, Brazil, Portugal. We try hard to perform a roundtable at end and with particular issues to get reinforcement and acknowledgement. Usually get 'kind-of a yes' response, but they rarely request for clarification. Not sure what "yes" means – we heard you? We understand? We'll take action? Meaning is unclear."
>
> "Participation – getting people to say what is on their minds, especially South America. They don't say how they feel when unhappy with a decision."

Time zone and language barriers were a common theme when discussing problems that occur in the course of conducting global team meetings:

> "Difficulties – time zone and language barriers. Routinely have difficulties with Mexico with language. Can have good conversation with senior managers, but engineers have trouble with English."
>
> Difficulties include that sometimes it is difficult to understand what people feel and mean. Eye contact is so important when you are having discussions. Other difficulties are time zones, schedule demands and the fact that the priority is to customers – not to attending meetings.
>
> "At the end of the meeting, a Mexico participant acknowledged that it was difficult to understand the British accent. I wished he had made his request for slower, clearer talk at the beginning."

Protocols were often viewed as an informal, undocumented understanding of how the team should conduct meetings. Examples of effective protocols to overcome some of the difficulties associated with global meetings include:

- Standards for minutes and agenda formats are observed

- Utilize face-to-face on a regular basis to build relationships

- Use roll call of all participants to confirm consensus or agreement on key issues or decisions.

- Participants clearly identify themselves by name whenever speaking.

Team Processes

Participation was viewed as key to facilitating team processes and decision-making. Protocols were needed to ensure that every site in a virtual team meeting had the information being discussed. While periodic face-to-face meetings helped to create trust, the adherence to protocols as part of regular team processes helped to reinforce such trust on an ongoing basis. Additional trust maintenance was provided with the timely follow-up on action items from team meetings, and leadership was viewed as a key role in ensuring that such discipline was maintained.

When asked about formats of information used by the team, there was a mixed response. In many instances, the data of concern in a given team meeting is obtained from other sources outside the team, and formats can vary widely. However, it was felt that standard formats improved the understanding and facilitated discussion of information.

Participation in global teams has also impacted the business practices of participants. Time zone differences had a significant effect upon work hours especially when participation from

sites in Asia was involved. Technology was viewed as a facilitator of business practices, but also created a sense of frustration and dependence:

> "Having the ability to do my job remotely – not tied to the facility. Feel boat-anchored to the computer, though. I have freedom otherwise, even with PC's at home and work, palm pilot, etc."
>
> "We have become slaves to email and the PC. People are often forced to do email while on vacation."

Regarding the performance of the global team and the impact on the individual performance evaluation, subjects generally felt that the global team performance suffered when individual performance was measured against local objectives that did not consider or were not aligned with the objectives of the team.

Communication Media

Most common media used in global teams included email, voice, face-to-face, web documents and other shared databases, pagers and fax. Teams generally performed better when using a variety of media. Frustration was evident in cases where teams limited themselves to certain media, especially when the opportunity for face-to-face meetings was not available:

> "Sometimes they [remote sites] think they are always on the receiving end. Europe, other people just ask questions and otherwise never participate. They are creating the perception that we're not communicating. Have not been to Europe to meet with them in person."

Preferences for media varied. Some preferred voice to email, while for others the opposite was true. While such differences in preferences were identified, it was generally difficult to determine if any correlation existed with overall team processes or other accepted protocols. Such preferences tended to be very individualistic. Those who desired convenience and the

ability to maintain a record of discussions favored email, while others favored voice communications due to its ability to be more conducive to personal interaction.

When asked about the timeliness of responses to messages sent, most subjects were satisfied. However some frustrations existed that arose from the fact that others did not share or appreciate the level of urgency desired. In some cases, people found themselves unable to respond to all requests due to the overwhelming quantity of emails received. The sheer volume of information received by email requires that actionable requests be clearly identified. Otherwise such requests can get lost among the many emails that are received for information only purposes. When individuals are overloaded with email, many consider it standard practice to ignore information only emails when received. Voice communications generally outperformed email when feedback and response was desired.

Organizational Learning

Questions related to organizational focused on the accessibility and availability of information necessary for the team to complete its tasks. While much effort has been focused on developing corporate information databases and websites, most interviewees indicated that they still relied substantially on personal contacts and networks to get the information they needed. Sample quotes include:

> "Through personal relationship building – without that you won't get information. There is only so much information you can get from web or e-mail. If you don't know where to get the information you at least need to know who to go to in order to track it down. That kind of knowledge building requires personal relationships. There is no electronic equivalent."

> "The vast majority is through personal networking. There is no repository of information or training, except for engineering standards and technical drawings... Phone directories and org charts are important. Sometimes I am making six phone calls to find the right person."

In order to facilitate the exchange of knowledge and information globally, communication media needs to support the capability of building relationships and personal networks. It is not surprising that the predominant choice for seeking information when it is not clearly defined whom to contact directly is using voice or face-to-face meetings that allow a greater degree of personal contact.

Language and Cultural Issues

As discussed above, language barriers are a significant factor in global teams. In order to reduce the effect of language differences, it is necessary to slow down the pace of conversation to allow others the time to undergo the process of translating verbal statements into their own language and formulate a response. Language barriers are often evidenced by silence from remote sites and are therefore difficult to detect.

> "We tend to talk fast. I try to talk slower, louder so everyone can understand and translate in their head. We tend to expect fast answers, while they are still translating. Need to ask for confirmation of understanding. They feel it is a deficiency – can't offend them. If they do not know something, they are afraid to admit it. Not knowing is considered bad – a sign of weakness – Mexico, Brazil."

Visual cues are important in reducing the effect of language barriers but are not always entirely effective. This can be seen in the contrast between the following quotes from different interviewees:

> I can listen to dialogue between two different cultures and know when person doesn't get the message. To get a sense of what goes over their head, visual is a big part of that feedback.

> "When someone nods – you think he understands but has actually has no idea."

One subject that spent a substantial amount of time dealing with Japanese suppliers found that his ability to gain trust and successfully conduct business improved dramatically as a result of studying Japanese language and culture. While meetings were conducted in English, he found that the ability to interject phrases or words significantly helped improve communication. This was attributed in part to the heightened sensitivity for the need for others to translate verbal statements while interacting in a conversation. However, the real value of learning other languages was that it helps increase the level of trust and deepens the relationship with members of other nationalities.

When asked about cultural differences, most interviewees felt that the associated language differences were the biggest source of communication problems. However, other statements reflect the consequences of different power-distance relationships that exist between cultures.

> "Speaking out to management is the biggest cultural difference. Management has status, and if a manager is present in a meeting in Mexico and he asks something, they [Mexico site] expect the team leader [in North America] to answer. Not them – even if they have the information, since it is perceived that the leader's job is to answer to management. You have to ask and ask clearly for opinions sometimes."

One of the female subjects in the interview also commented on the frustrations due to the perception of power associated with masculinity predominant in some cultures:

> "Some cultures don't accept instructions from women."

Despite all the problems and barriers associated with global teams and working with different cultures, the subjects generally agreed that there was significant value in the diversity offered by global teams:

> "The dichotomy is that the difficulties are some of our strengths. Diversity makes it hard to understand, but adds to the overall power of the team."

Technology

Apart from the media discussed above, other complementary technologies that supported communication in global teams included the use of digital pictures and video. When problems occur at customer manufacturing site, it is possible to take digital photographs and video to be sent along with a standard email to others at remote locations to better illustrate the issue.

One interviewee voiced the following apprehensive view to technology:

> "Make it human. E-mail dehumanizes. We got sucked into technology too quick. The next generation may be more able to cope with technology. Our generation relies on humanizing things. Every culture wants to humanize."

Other technologies that were suggested as possible improvements to the communication environment included wider use of personal digital assistants (PDA's), net meeting and increased utilization of videoconferencing.

3.2 The ZMET Interview

The Sponsor Company interviews confirmed that communication is a vital element in today's workplace and society as a whole. Technology is constantly changing, offering users many different choices of how to send and receive information. Choices range from face-to-face

conversation to paper letters, telephones, cellular phones, pagers, and e-mail among others. It is very common today to find people carrying more than one form of communication device at any given time. It is important to understand what drives communication choices and what may be lacking in the tools that are available today. The objective of this phase of the research was to understand how users view the communication process and the choices that are available to them. A patented interview process was employed to determine the factors and needs that drive the choice of which communication media to use, assess the preferences for particular media, and investigate what may be lacking in all of the available choices.

3.2.1 Description of the ZMET Methodology

The interview process used in this phase of the study was the Zaltman Metaphor Elicitation Technique – ZMET (Zaltman, 1997). The ZMET process extracts metaphors from images collected by interview subjects. The concepts behind metaphor elicitation methods are based on observations from behavioral, social and biological sciences. Some of the key principles underlying the process include:

1. Thoughts Occur as Images – Rarely do thoughts appear as text or words. Images are the primary form of thought that occurs within the mind. Verbal descriptions are only added as the brain processes and moves images to language processing centers in order to make decisions. By introducing images in order to elicit responses, the ZMET method increases the effectiveness of research in its ability to capture thoughts and feelings.

2. Most Communication is Nonverbal – Estimates vary, but as much as two-thirds of human meaning is shared nonverbally. This is a consequence of the fact that, on an evolutionary scale, verbal language is a relatively recent development in humans. Paradoxically, most research is performed only on a text or spoken word basis.

3. Metaphor is Central to Thought – Metaphors are the representation of one thing in terms of another. This is analogous to the discussion of communication media (McLuhan, 1964) in that media are metaphors themselves. By utilizing images, the ZMET approach extends research to other media to better capture the underlying metaphors that define cognition.

4. Cognition is Embodied Experience – Abstract thought is shaped by physical, perceptual and motor experiences. This is evidenced by the fact that many espoused metaphors relate to physical perception. ZMET research is intended to decipher thought to capture and define the collective experience.

5. Mental Models Guide the Selection and Processing of Stimuli – Mental models consist of iconic imagery and represent an inner map by which cognition occurs. The attention or focus of conscious behavior is directed and motivated by such mental models. Perception and behavioral responses are subconsciously filtered and can be limited to those that are consistent with such internal mappings. ZMET attempts to facilitate the construction of socially shared mental models to represent underlying thought processes and associations between them.

In the ZMET process, each subject is asked to provide from six to twelve pictures that contain images related to a particular topic or product. The subjects are given a period of several days to collect the images. Such pictures can be from existing images, such as magazine clippings, or from objects in their surroundings as captured in photographs they take themselves. By having the subjects gather the images themselves from their surroundings, the ability to capture emotions and feelings relevant to the subject is enhanced over other methods wherein the researcher provide such images.

During a structured interview, the images provided by the subject are reviewed and probing questions are asked in order to elicit metaphors and emotions captured by the images. The interview lasts approximately one hour and is placed in a setting that is conducive to casual conversation. During the interview process, customer statements – or "voices" – are recorded for later processing and analysis. The intent of the interview is to allow the subject to espouse the meaning of each picture, thus avoiding the likelihood that predefined research questions will be leading in some form or fashion.

Once several subjects have been interviewed and the voices have been transcribed, individual statements – or "customer voices" – are extracted. These voices then undergo a further process – called "scrubbing" – wherein they are collected into similar groups that reiterate the same statements. Each group of similar statements is then labeled with a common voice or statement that reflects the collection of statements in the group. Occasionally, such scrubbed voices may represent only a single, individual statement. The scrubbed voices are then categorized into related topics into a hierarchical structure of needs that can be presented as an Affinity Diagram or Consensus Map. Both of these mappings capture the associations

between different needs or grouping of needs. In this research we utilize the Affinity Diagram. Using the needs defined in an Affinity Diagram, a survey will be developed that can be administered to a wider population for further research.

3.2.2 The ZMET Interview

To understand communication needs, we conducted one-on-one in-depth interviews with individuals that represented a variety of business and personal communication users. In order to maintain consistency in the interview process and data gathering, an interview guide was developed and used in structuring all of the interviews. The interview guide is included in the Appendix II.

Three subjects were selected and interviewed based upon their diverse communication needs and exposure to a wide variety of communication media. All subjects were in the 30-40 year-old range and their profiles are summarized as follows:

- The first subject was a female graduate student. This individual has prior business experience in working within dispersed teams. As a foreign student, she also maintains frequent personal communications with her family and close friends located in other continents.

- The second subject was a female software technician working at a major US corporation. This individual has frequent business communication needs (domestic & international), but the interview concentrated mostly on her personal communication needs.

- The third interviewee was a male business executive at a software startup company. This person has extensive information technology experience and is clearly a lead user of technologies having developed many applications to facilitate his communications needs.

Upon recruiting subjects and prior to the actual interviews, the subjects were briefly introduced to the topic of interest and the objectives of the study. They were then asked to locate pictures that captured their thoughts and feelings about communication as part of the ZMET process. The intent of gathering images related to the topic is to prompt and elicit deeper, hidden emotions and feelings about communication that may not surface as part of the verbal conversation occurring during the interview process. Images allow the subjects to better express themselves about the topic by creating and expressing associations between objects and their communication needs.

Using the interview guide, structured questions and a process for eliciting the interpretation of the images were followed. Each of the interviews was approximately one hour in duration. Every attempt was made to maintain a casual atmosphere and probing questions were used as necessary to reinforce the questions in the guide. The entire interview was audio taped to avoid distractions arising from taking notes. This allowed for the entire interview to proceed as if it were a casual conversation.

In order to capture the comments and attitudes conveyed during the interview process, each taped interview was accurately transcribed. This allowed for further processing of the

interview content and subsequent grouping and analysis of the individual responses from each interview.

To identify specific communication needs, relevant statements or quotes were selected from the interviews that espouse a particular need or other attribute that determines the level of satisfaction or dissatisfaction with communication. Approximately 137 individual quotes or "voices" were captured and then grouped into categories that reflected a common need. In some cases, individual quotes identified a need that was unique from all others and were kept separate to define a unique category. This grouping process resulted in 34 unique categories of "customer voices" representing individual needs associated with communication.

Further processing or "scrubbing" of the individual needs was performed, wherein the voices in the groups were consolidated into a statement of needs that reflected all voices in each group. This required some interpretation and refinement of the need statements to make them more general without losing the specific meaning of the groups of voices represented by the statements. Once the scrubbed voices were generated, a further higher-level grouping was conducted to develop a higher-level category of associated needs. For example, "Ease of Use" was a common theme espoused by individual needs relating to speed, timeliness and utility.

Using the hierarchy of needs derived from the scrubbed voices, an Affinity Diagram was developed that captures the relationship between specific needs, as derived from the customer voices, and higher level needs generated during the scrubbing process. This Affinity Diagram is presented in Figure 3.1.

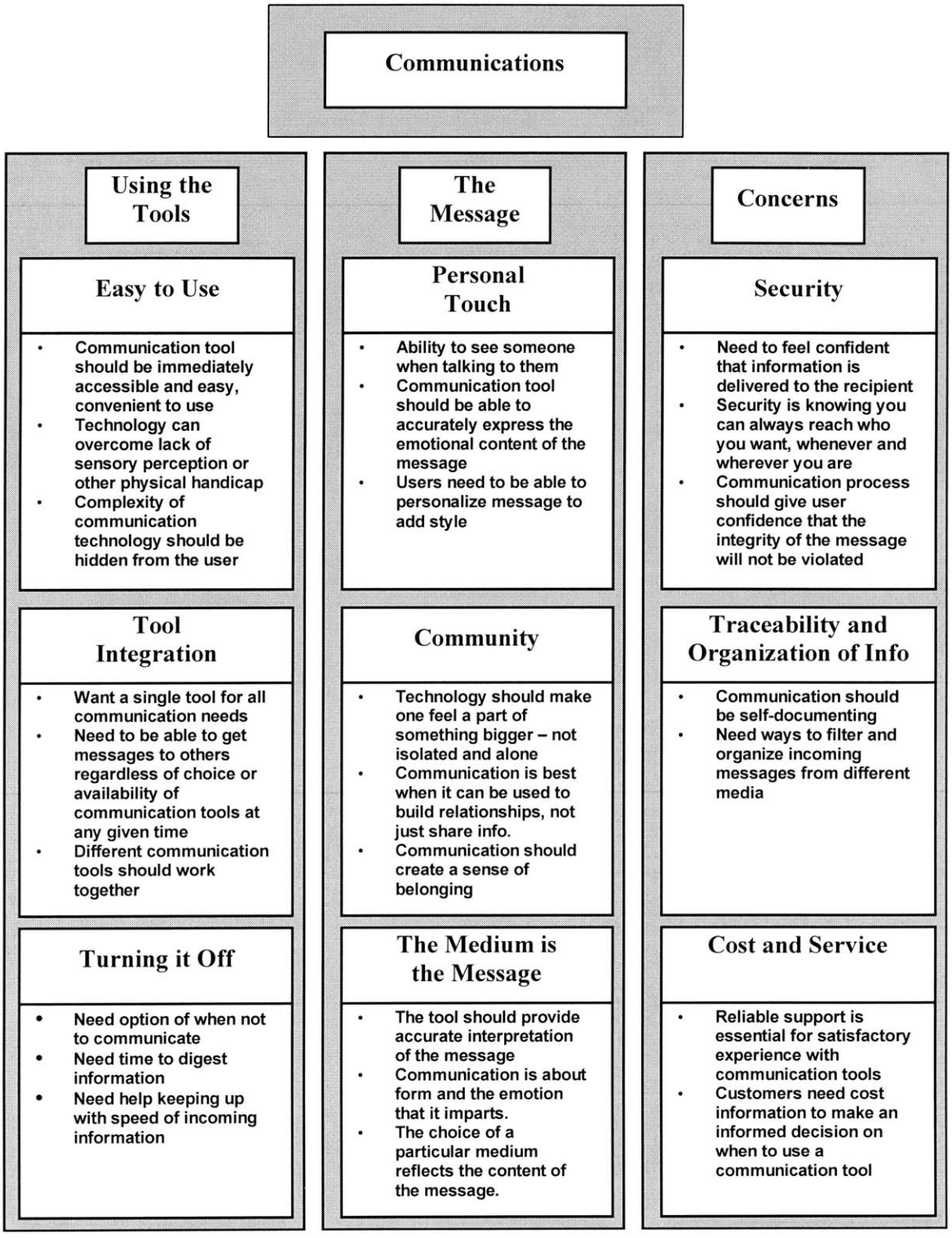

Figure 3.1: Affinity Diagram

The following section describes the elements of the diagram in more detail and includes examples of some of the quotes gathered from the customer interview process.

3.2.3 Interpretation of the Affinity Diagram

Three major groupings of associated communication needs were identified in the ZMET interview. These higher level needs are denoted by the terms as: The Message, Using the Tools and Concerns. These needs and the associated categorized needs are described in detail below.

The Message

Communication is all about conveying a message to someone. During our interviews and research, we have found that people do not generally feel that today's technological choices have made the message more effective. An important part of the message is the personal and emotional elements. The respondents shared the view that most available choices of communication media are less personal and lack the ability to deliver the true intent of the message. They want to be able to deliver the emotional aspect of a message and have it interpreted correctly. Because of this, the intent of the message will often play a role in the choice of the media that will be used to deliver it. With the loss of emotional content the subjects generally felt apprehensive with regard to their choices. Furthermore, the increasing complexity of the communication technologies generated a perception of insignificance and insecurity with technology in general. The personal element needs to be reintegrated into the message.

Communication Should Enable Conveyance of Emotions

As one subject stated: "I want to know what the other person is feeling." Human evolution has allowed us to interpret other people's emotions through voice and visual cues. As technology has advanced, we have become more reliant on text based messaging and as a result, the recipient of the message has been denied the ability to read these clues. Voice communication media adds tones, inflections, and accentuation. Face-to-face and visual communications add the ability to send or interpret physical signals. This requirement was evidenced in our interviews by the high value that was associated with the need for being able to see the person that you are talking to.

A common complaint was that the technologies existing today do not always convey the emotional aspect of a message. There is a need to accurately express emotions when sending a message. In an extreme case, sending a message of extraordinarily good or bad news through text does not create the hype that would probably accompany a voice or face-to-face exchange in these circumstances.

As a step towards re-emphasizing the emotional and personal touch of a message, an interviewee expressed the need to personalize the style of the message that is being sent. Personalization of style could help evoke emotions and emphasis of the content, thereby giving the users additional power to accurately communicate all aspects of the message – including emotions.

The choice of the communication media often determines how the message will be interpreted. As previously discussed, some communication choices deny emotional

conveyance in messages. The intent of the content often influences which form of communication media is chosen. E-mail and text based messages do not portray emotions and therefore are usually used for business communiqué, fact based messages, or messages requiring documentation. Messages requiring the emotional and personal element are often conveyed in voice or visual forms of communication and are most often accomplished through telephone calls or face-to-face visits. For instance, several interviewees talked about "flowers" as a form of communication. This visual and sensual form often instills strong emotions and it is difficult to imagine its users replacing this form of communication with any technology that exists today while still being as effective.

Media Should Facilitate Creating a Sense of Community

During the interviews, people expressed the uneasy feeling of being alone even in the midst of today's numerous communication choices. The respondents thought that communication tools should allow people to integrate themselves into, or feel that they were a part of, a community. A problem that appears to be occurring with advancing technologies is that users begin to feel insignificant in the whole scheme of everything. As the technologies have taken the emotional and personal aspects out of our messages, the line of communication has begun to appear more complex and there is a lack of understanding as users begin to use all of the new choices. When discussing the increasing use of the Internet as a communication tool, an interviewee stated that "the Internet makes me feel very small" and that they think of the Internet as "...one single person solitary in a room." Communication choices are missing the personal intimate connection between people that give them a feeling of belonging.

People generally feel that communication tools should allow them to connect with other people without the feeling that they are either alone or insignificant. This will result in the requirement that communication tools appear simple to the user and that the tools allow the user to remain in constant contact with friends and family.

With the advancing technologies and the Internet, we are gaining access to a larger world and we have quicker access to information. With these advancements, people are feeling overwhelmed with the new choices and alone as they lose the personal element.

Using the Tools

Users want to feel that their lives are enabled by communications as opposed to being ruled by them. This duality of power and weakness was a common theme for many of the users. While they uniformly recognized the features of communications, they were also intimidated by the technology and also of the community effects of a communications channel.

Users Need to "Shut Down" Communications at Will

One of the negatives of constant communications within a community is the need or obligation that a receiver feels to reply; a communication thread involves both a sender and receiver to be effective. As one user stated, "It's great to be able to communicate with anyone you want, but then you will be communicating with a lot of people you don't want to". The subjects favored a simplistic method offering the ability to withdraw from the community in response to a large influx of communications received. This can often take the form of just shutting down the communications medium. The technology apprehension is most probably rooted in the perception that technology is surrounding their lives with little

opportunity to escape. According to one user, "Technology - it is at a point where it's hard to ignore people anymore". This feeling that the very tool that they value for communicating with other people is actually the same tool that they loathe when answering poses an interesting paradox.

Communications Tools Should Enable both Efficiency and Effectiveness

There is a major gap forming that divides the efficiency and effectiveness of media. Several interviewees commented that the speed of communications was not only a positive feature but actually a negative one as well: "The other challenge is that information can now be delivered to you at high rate of speed anywhere on the planet at any time, day or night," and "...with the speed of information are we making better decisions or just faster decisions?" One subject added to this the notion that when one sends an email to someone, they expect a response very quickly since the medium of email is almost instantaneous. While the belief was shared that information was being delivered very fast (efficiency), there was a major reduction in actual interpretation and making good decisions (effectiveness).

Users Require Simplicity and Convenient Access to Communications Tools

Convenience is also a major need that reinforces the idea that communication tools should be enabler. This not only appeared in quotes reemphasizing the usability aspect of communications, "[the] telephone is the easiest form of communication", but also in the sense of being easy to approach, "...openness - it (communication) is not cluttered, just really straight forward". Another user also hinted at the preference that technology should conceal its own underlying complexity: "The technology behind communicating is very complicated." The actual degree of complexity experienced with using certain technologies

and the perception that even more complexity exists behind the scenes combined to yield a very apprehensive view of technology itself. It should be emphasized that communication should not only enable the seasoned user but also be designed so as not to intimidate the new or casual user.

Integration of Media Enables Communication

The large influx of communication choices has yielded a need from the users for not only simplicity (reemphasizing the ease of use aspect) but also integration of communications channels. One user highlighted that the increase in the number of options may actually be decreasing our effectiveness: "There always seems to be many methods of communicating. None are very effective". Another user reemphasized that there are "too many options!" The large number of choices also posed confusion to the users as to which method would be the most appropriate. While many users were most comfortable with voice or face-to-face contact, it is usually the practice to use the same media for reply in which messages are received. In effect, the user places a media context to each of his contacts. This highlights not only the need for integrating different media, but also indirectly arises from issues surrounding the ease of use and simplicity.

Concerns

When users have made a choice about the form of communication media to use, service and reliability become an important aspect of their communication experience. In fact, the service and reliability can play a key role in which service is chosen to communicate.

Users Need Reliable, Cost Efficient Service to Support Communication Tools

Many users of communication tools find themselves disappointed by the service and support accompanying the product. Annoyances with service tend to be attributed to the service provider brand name. Such association often holds true even if the communication hardware device and service provider are different brands. Even when there are problems with the hardware, the user is likely to associate their dissatisfaction with the service provider instead.

Cost of service is also critical in guiding the users choice to utilize a particular service. The relative cost comparison in selecting a particular communication medium is based upon consumer perceptions of sunk and variable costs. For example, local phone calls are often perceived as free when included in a base rate plan. On the other hand, long distance phone calls are perceived as being more expensive than using e-mail, and users must decide whether the cost savings are enough to offset the reduced capability of text-based email to convey emotional content and support relationship building as compared with voice.

Users Want Confidence that the Integrity of the Messages Will Not Be Compromised

One of the more frustrating experiences is when a message is lost or not delivered. This is particularly true when there is emotional or personal content associated with the message. For example, a hand-written letter to a close friend can create significant dissatisfaction if the letter is subsequently lost in the mail. One subject recounted such a specific occurrence, even though the event happened many years in the past. The annoyance was heightened by the fact that any indication that the message was lost is separated in time from the occasion of original composition. The personalized emotional content captured at the moment of writing may be difficult to recreate at a later time, and the lack of the anticipated reply to the

letter can strain the relationship the letter was intended to reinforce. As communication becomes more personalized, there is a heightened need for reliability of service, as any dissatisfaction with failure in the communication process becomes significantly increased.

Access to communication also imparts a certain sense of security. As one interviewee stated, "Communication lets others around the world know that you are safe." Having the confidence that you can reach anyone, anywhere in the world at any given time is important. This allows people to "stay in touch" and also fosters closer, family-like relationships with others around the world. Technology is perceived as promoting closeness and the ability to share information with others. Technology "brings people together from all walks of life."

Media Should Facilitate Structuring and Organization of Information

According to one subject, there is "so much input from so many different sources, and you're going to have to filter through all of them to sort out what you want to hear from what you don't want to hear." The ability to sort and filter incoming messages is critical to users, especially in business, where the primary form of communication is e-mail. The unique benefit of e-mail is that it offers documentation and a record of the communication. However, the task of managing the volume of information is overwhelming. E-mail and related forms of communication need to be self-documenting and self-organizing to alleviate this problem. This problem is further complicated by the reliance on many paths of communication across different media. It is often difficult to reconstruct mentally how a particular message was sent and the path that it took to get to the recipient.

Proposed Concepts for Future Communication Media

Several proposed concepts can be derived from the ZMET interview data that can be applied to evaluate the selection of future communication media solutions. These include:

1. Ability to identify the intent of the receiver prior to sending the message.

   This would address the issue of not knowing if the message is actually going to be read. Some email systems have this feature in a rudimentary form in that an automatic reply message can be sent to the sender if the person is for example out of the office. An automated software agent that would automatically recognize your intentions and direct the communications accordingly would be ideal.

2. Integration of video and voice messages

   This concept would enable the sending of a digitized video as an email attachment or even to a web enabled phone. In the latter concept, a video picture of the message can be retrieved on a phone with a small screen that is attached to the Internet. The person's video would play with the voice being transmitted in the phone. This would address the need for viewing and hearing emotions while the phone interface would enable simplicity and ease of use.

3. Communities that extend across media

   This concept would extend the notion of communities and the sense of belonging to various media forms. Typically, communities are single channel in that they are email

or instant messaging based. This would integrate the media into one "community channel" and enable all forms of communications such as voice, video, and text.

3.3 Communication Needs Survey

Using the needs defined in the Affinity Diagram, a subset was selected for generating a survey designed to assess the relative importance of needs and the utility with which certain media satisfy these needs. Since the surveys used in the research also asked other questions related to demographics and global teams, it was necessary to limit the number of needs surveyed in order to maintain the time required to complete the surveys to within an acceptable range.

Subsequent surveys administered as part of this research included questions designed to assess which communication needs were significant and which media performed well against these needs. Two separate surveys were generated and administered to different respondent populations.

The first survey was administered to a control population and included questions related to communication needs as derived from the Affinity Diagram along with other demographic questions. The control population allowed for a comparison of media utilities as derived from the results of the Sponsor Company survey. The control population demographics included a mix of college students and working professionals. The specific job responsibilities of the respondents ranged from job functions that included product development, engineering, sales and marketing activities. Approximately 20% of the respondents were female, and the age groups represented by the entire sample ranged from

20 to over 45 years old. This survey is referred to as the "control survey" throughout this document.

The second survey was administered to members of global teams within the Sponsor Company to assess not only communication needs, but also how those needs changed in the presence of cultural and language communication barriers frequently encountered with global team interaction. This survey is also referred to as the "sample survey" throughout this document. The sample survey respondents consisted of working professionals within the Sponsor Company that had experience as members of globally dispersed teams. A total of 24 survey responses were received from Japan, France, Germany, North America and the United Kingdom. The respondents represented a breadth of functions in the Sponsor Company, including product development, marketing, customer Sales and Service and manufacturing.

The communication needs derived from the Affinity Diagram and employed in the survey were summarized by the following six key needs:

1. Ease of Use – reflects the overall user friendliness of the medium

2. Ability to Personalize – relates to the ability of media to support personalization and conveyance of emotional content

3. Feedback – identifies the ability of communication media to generate a sense of confidence the message was interpreted accurately as intended

4. Security – relates to the degree of confidence that the integrity and confidentiality of the message will not be compromised

5. Ability to Organize – indicates the overall ability of media to support traceability and organization of information

6. Reliability and Service – includes the satisfaction with the reliability of the media and supporting services

Questions relating to the level of satisfaction experienced by respondents for each media type included in the research were asked. Media studied included E-Mail, Video, Face-to-Face, Voice, Shared Documents, Fax and Pager. Video referred to synchronous video conferencing technologies. Shared documents included electronic files stored in shared databases and those available on the World Wide Web or corporate intranets. Pagers included both numeric and text pagers.

Additional questions were designed to assess the relative importance of each of the needs in the context of different modes of knowledge transfer as defined by the Nonaka theory of knowledge creation (Nonaka, 1996) discussed in Section 2.6. These questions were structured to capture all four combination of knowledge transfer between tacit and explicit forms. The four sets of questions were posed in a situational context as follows:

1. Tacit-to-Explicit – Teach or explain how to perform a specific task that is not well documented. This situation refers to the translation of the tacit understanding of how to perform a task into an explicit set of instructions for others to follow.

2. Tacit-to-Tacit – Describe the appearance, behavior or some other attribute of an object. In this case, knowledge that is tacit (look and feel) is conveyed so as to instill a sense of similar look and feel in others.

3. Explicit-to-Tacit – Discuss concepts, share insights or brainstorm new ideas. In this scenario, knowledge that is understood and can be easily structured into itemized list of metaphors is explained in a fashion so as to allow others to understand the significance underlying the metaphor.

4. Explicit-to-Explicit – Convey an established, well-documented process or procedure. This situation concerns the transmittal of information that is in a formal syntax or format characteristic of explicit knowledge.

The complete surveys are included in Appendix III and Appendix IV. Further discussion of the survey objectives and results is included in Chapter 4.

3.4 Comparison of ZMET Needs to Sponsor Company Interviews

The following section reviews and compares the needs as identified by the ZMET method with the findings from the Sponsor Company interviews discussed in Section 3.1. The purpose of the discussion in this section is to confirm the relevancy of the needs derived from the ZMET process to the Sponsor Company population.

3.4.1 Ease of Use

This need is associated with the preference for communication tools that are accessible whenever needed and easy, convenient to use. Furthermore, Ease-of-Use is associated with

the ability for technology to overcome the lack of sensory perception or other physical handicap. Finally, complexity of communication technology should be hidden from the user.

During the Sponsor Company interviews, the need for Ease-of-Use was a valid concern that generally arose when discussing the difficulties or frustrations associated with using certain technologies. For example,

> "Difficulties – logistics. We can't successfully connect all sites. BT (British Telecom) controls the coordination, and it is difficult to add sites."
>
> "I have voice mail, a pager, cell phone, two answering machines, fax, email, web communication, a PDA, and I still can't reach anybody! We've complicated communications with too many media."

3.3.2 Ability to Personalize

This need is related to the fact that users of communication tools need to be able to personalize messages to add style. Examples of this include the ability to actually see someone when talking to them. The communication tool should be able to accurately express the emotional content of the message. Several quotes relating to the need to create relationships and build trust were voiced in the discussion of the Sponsor Company interviews. Users frequently consider the personal element when deciding which medium to employ. For example, one Sponsor Company interviewee stated the preference for voice communications over email:

> "Mostly by phone, because it is most personal."

3.4.3 Feedback

The need for feedback and frustrations when this need was not met was a recurring theme in the discussions with Sponsor Company global team members:

> "If people would return calls, answer phones, we wouldn't need any other media."
>
> "The weak link – no one answers because they're too busy – the obligation is still on the caller. The weak link now is for the receiver to process the message."

3.4.4 Security

Security is the need to feel reassured that information is delivered to the recipient and that the communication tool offers assurance that the integrity of the message will not be violated. While security was not directly related to any of the questions from the original interview questionnaire, an example of some of the comments indirectly related to the issue includes the following relating to audio conferencing:

> "Sometimes sporadic sites come in and interrupt the meeting. Can't control which sites are connected."

The fact that security was identified as a key need as a result of the ZMET process demonstrates the utility of the method in extracting a more complete set of needs from a smaller group of interviewees. Although the Sponsor Company questionnaire did not intentionally omit questions relating to specifically address security issues, it is unlikely that the need would have been identified as a result of the questionnaire based interview process. This illustrates the power of metaphors employed in the ZMET process to extract hidden, deeper meanings while avoiding the potential for bias introduced by the researcher.

3.4.5 Organization and Sorting

With the volume of information transfer enabled by technology, the need for communication tools to support the ability of information to be self-documenting and support the ability to

filter and organize incoming messages from different media is vital. Examples from the Sponsor Company interviews include:

> "Improvements – File availability, websites or e-mail. Paper copies are not adequate and are never forwarded."
>
> "More communication with e-mail requires that greater ability to be able to prioritize and send requests with appropriate timing"
>
> "The trick is not getting all the information, it's managing it."
>
> "You can't do a functional search in the directory within Outlook."

3.4.6 Reliability and Service

Reliable support is essential for satisfactory experience with communication tools. This was reiterated many times during the Sponsor Company interviews:

> "Sometimes the bridge doesn't happen"
>
> "Teleconference works well. Video is an effective media. Rarely let us down – reliable."
>
> "The digital phone is a failure. Every fifth call gets dropped"

Based on the comparison between the two methods, we can conclude that the set of needs derived using metaphor elicitation is valid among the Sponsor Company population. Furthermore, the value of combining different interviewing methodologies is evidenced by the enhanced structure and understanding of the underlying needs associated with communication.

4.0 Survey Data Analysis

Survey instruments were administered to both a control and a sample population to assess the relative importance of communication needs grouped according to different modes of communication. The control survey also included questions to provide additional data relative to the population segmentation according to age, gender and the history of adopting new communication technologies such as PDA's. The sample population survey also contained additional questions to determine how communication needs varied in the presence of cultural and language barriers to communication and to assess the relative strength of such barriers encountered with different countries and geographical areas. Both surveys also asked questions related to the effectiveness of certain media in satisfying the communication needs.

The control survey was administered to a group of 60 individuals with a total of 32 responses received. The control population demographics included a mix of college students and working professionals. The specific job responsibilities of the respondents ranged from job functions that included product development, engineering, sales and marketing activities. Approximately 20% of the respondents were female, and the age groups represented by the entire sample ranged from 20 to over 45 years old. Relative adoption of PDA's in the control sample was equally balanced, ranging from early adopters to those who did not own such devices.

The objective of the control survey was as follows:

- Assess the relative importance of communication needs

- Identify differences in communication needs with respect to age, gender and the likelihood of adopting new communication technologies

- Identify other natural clusters or segments of respondents that exist with regard to preferences related to the communication needs surveyed

- Determine the effectiveness (utility) of media in satisfying the needs

The sample survey respondents consisted of working professionals within the Sponsor Company that had experience as members of globally dispersed teams. A total of 24 survey responses were received from Japan, France, Germany, North America and the United Kingdom. The respondents represented a breadth of functions in the Sponsor Company, including product development, marketing, customer Sales and Service and manufacturing. While all of the respondents were fluent in English, most indicated that English was their native language. Since most global regions where English was not the local language were represented by individuals indicating English as their native language, it is likely that such respondents are in fact expatriates working in foreign assignments. The survey did not explicitly ask questions with regard to international assignment status nor was it designed to distinguish among expatriates and local nationals responding from any given region. More than half of the sample survey respondents worked outside of North America.

The objective of the survey administered to the sample Sponsor Company population was to:

- Compare the relative importance of communication needs between the sample and control population and understand any variation of needs

- Identify segments of sample survey respondents that exist with regard to preferences related to the communication needs surveyed

- Determine the perceived utility of media as compared with the control survey population

- Assess the impact of the presence of language and cultural barriers upon communication needs

- Determine the relative strength of cultural and language barriers present in communication between specific countries or geographical regions

- Derive a revised utility of media considering the modified needs associated with communication barriers

The results of the sample survey data were also used to develop a method for quantifying communication effectiveness or utility rankings between globally dispersed virtual team members. These utility rankings are employed in a quantitative analysis of the structure of communication including the effects of using different media and presence of language and cultural barriers to communication.

4.1 Statistical Analysis of Control Survey Data

The statistical methods employed were factor analysis, cluster analysis and calculation of media utility rankings with respect to the needs. Additional analyses included a comparison of correlated factors with the frequency of media usage and a summary of pair-wise

correlation among responses to individual survey questions. In deriving the results from the survey, correlations, factor analysis and clustering were performed using JMP v4.0 software, while the utility calculations for media used an Excel spreadsheet.

4.1.1 Factor Analysis

Factor analysis is a statistical procedure that uses the correlations of responses to a large set of variables that simplify the structure of the variables into a reduced set of factors. By focusing on the interrelationships displayed in the entire set of survey responses, factor analysis provides an efficient means for data reduction and substantive interpretation. Data reduction is achieved through the summary of data from many separate survey response questions into a fewer number of factors. These factors are computed based upon the correlation between responses to individual questions. In effect, the factors measure the covariance of answers to survey questions across the entire population of respondents. Questions that solicited similar responses from the sample population are grouped in a common factor, allowing for the aggregation of survey data into a compact form represented by the most significant factors derived from the correlation of responses to all survey questions.

Factor analysis facilitates interpretation of the set of data by inferring a number of underlying dimensions that explain a correlated set of survey responses. Based on a derived factor from a data set, a new variable, called a factor score, can be developed to indicate the extent to which each respondent possesses or lacks the dimension represented by the particular factor. A factor score can be treated as if it were itself a survey question or variable in that it is an aggregation of the data contained in a number of individual survey questions. The extent to

which a factor captures data in the dataset is measured by the associated eigenvalue. The eigenvalue can be represented as a cumulative percentage that indicates the percent of the correlation information from the entire dataset captured by the factor. Such new factor variables can be used as inputs to further analysis, such as cluster analysis, to derive further insight into the data. Factors can be rotated to increase interpretability. Factor rotation involves the transformation of factors into a more meaningful set of coordinate dimensions using linear combinations of the original factors. Factor rotation allows a set of factors to be transformed into a form more useful for comparison across the correlations between individual survey question responses. Rotated factors can then be compared to the survey questions to develop underlying trends in the responses. Based upon the trends observed in the significant correlation values in the rotated factors, factors can be named to create a label describing the overall association between responses. The JMP software was used for factor correlation and factor rotation analysis.

Factor analysis was performed using the raw data responses for a subset of the survey data consisting of questions related to the needs across different modes of communication. This procedure was then repeated for the same survey responses when the needs were weighted against the frequency that a particular respondent indicated a particular mode of communication was likely to occur. For example, for the Tacit-to-Explicit mode of communication, the frequency-weighting factor was computed as follows:

$$\text{T2E Frequency Weight} = \frac{\text{Frequency of Tacit-to-Explicit Mode of Communication}}{\text{Sum of Frequencies for Each Mode of Communication}}$$

The purpose of frequency dependent needs analysis was to assess the relative importance of communication needs based upon the likelihood that a particular mode of communication

and, hence, the associated importance of needs was encountered. Frequency-weighted results were computed using the JMP software on frequency-weighted data first computed using an Excel spreadsheet.

4.1.2 Cluster Analysis

Cluster analysis is useful in identifying groups of respondents with similar responses to the survey questions relating to communication needs in the context of different modes of communication. Cluster analysis involves the grouping of respondents so that there is as much similarity to responses within a group and differences between groups as possible. In effect, cluster analysis segments the respondents according to the correlation of their survey responses relative to the factor scores as described in Section 4.1.1. In performing such analysis, the JMP software was used with Ward's Method to develop a dendogram that represents the results of the cluster procedure. A dendogram is a tree structure representation of the respondents that indicates the relative similarity of respondents to the survey questions. The existence of distinct clusters or groupings of respondents relative to the correlated factors is determined by the number of significant branches in the tree diagram. An example of a dendogram is shown in Figure 4.1 and is discussed in detail in Section 4.2.5. A perceptual map or "spinning plot" can be generated based upon the cluster analysis to show different clusters of respondents as projected onto a plot where the axes are the principal rotated factors. Cluster analysis was performed for both the raw data principal rotated factors and those associated with the frequency-weighted data.

4.1.3 Utility of Media

Media utility rankings indicate how well the media satisfy the communication needs for a given mode of communication. Media utility rankings were developed based upon the relative importance of the needs as determined by the mean ranking of needs for the different modes of communication and the mean of the relative satisfaction rating for each medium. We illustrate this calculation for the utility ranking of E-Mail relative to the Tacit-to-Explicit (T2E) needs. For E-Mail, we have the mean ratings of the medium relative to the needs as defined by the following variables,

$\bar{x}_{Email,Ease}$ = Mean of ratings for E-Mail Ease-of-Use

$\bar{x}_{Email,Person}$ = Mean of ratings for E-Mail Ability-to-Personalize

$\bar{x}_{Email,Feedback}$ = Mean of ratings for E-Mail Feedback

$\bar{x}_{Email,Security}$ = Mean of ratings for E-Mail Security

$\bar{x}_{Email,Organize}$ = Mean of ratings for E-Mail Ability-to-Organize

$\bar{x}_{Email,Service}$ = Mean of ratings for E-Mail Reliability-and-Service

The utility of E-Mail for the Tacit-to-Explicit mode of communication can be calculated by multiplying each of the six ratings of needs by a weighting factor w_j such that

$$\sum_{j=1}^{6} w_j = 1$$

and summing to obtain the utility of E-Mail across the needs, so that

$$U_{Email,T2E} = \sum_{j=1}^{6} w_j \bar{x}_{Email,j}$$

where the index j = 1 to 6 correspond to the values associated with each of the six needs for which ratings were given by the respondents to the survey. If we were to choose to rate each of the needs equally, we could select the weighting factors, such that

$$w_i = \frac{1}{6} \text{ for all } i = 1 \text{ to } 6$$

However, such a weighting scheme would not reflect the differences associated with the ranking of needs from each respondent associated with the particular mode of communication that is of interest, as in this example for the Tacit-to-Explicit mode.

Therefore, we can introduce weighting factors associated with the Tacit-to-Explicit mode that satisfy the requirement that all weights sum to unity and that are derived from the rankings given for the importance of needs associated with the mode.

We define these weighting factors as follows:

$w_{T2E,Ease}$ = Weight Factor for Ease-of-Use in the Tacit-to-Explicit mode

$w_{T2E,Person}$ = Weight Factor for Ability-to-Personalize in the Tacit-to-Explicit mode

$w_{T2E,Feedback}$ = Weight Factor for Feedback in the Tacit-to-Explicit mode

$w_{Email,Security}$ = Weight Factor for Security in the Tacit-to-Explicit mode

$w_{T2E,Organize}$ = Weight Factor for Ability-to-Organize in the Tacit-to-Explicit mode

$w_{T2E,Service}$ = Weight Factor for Reliability-and-Service in the Tacit-to-Explicit mode

The values of these weighting factors can be derived from the responses given from the survey using the average value of ranked needs for the Tacit-to-Explicit mode of communication. For example, the weight applied to Ease-of-Use is calculated as follows:

$$w_{T2E,Ease} = \frac{\bar{y}_{T2E,Ease}}{\bar{y}_{T2E,Ease} + \bar{y}_{T2E,Person} + \bar{y}_{T2E,Feedback} + \bar{y}_{T2E,Security} + \bar{y}_{T2E,Organize} + \bar{y}_{T2E,Service}}$$

where, in general, $\bar{y}_{i,j}$ represents the mean ranking of the importance of the *j-th* need for the *i-th* mode of communication. The utility of E-Mail for the Tacit-to-Explicit mode of communication can then be calculated using the weighted needs for the communication mode of interest. The overall utility of E-Mail can be calculated by averaging the utilities for each mode of communication,

$$U_{Email} = \frac{U_{Email,T2E} + U_{Email,T2T} + U_{Email,E2T} + U_{Email,E2E}}{4}$$

where utilities are similarly calculated for E-Mail for each of the other modes of communication studied.

Media utility calculations were first calculated from the raw data sample of user responses. Using the frequency at which respondents also encountered the different modes of communication, frequency-weighted utilities were also calculated. Such frequency-weighted utilities reflect the relative importance of different modes of communication and their associated needs.

4.2 Control Survey Results

In performing the analysis of the survey data, results were first compared using the raw data as provided by the respondents. The analysis of raw data assumes that there is no difference in relative importance as indicated by the frequency at which different contexts of communication were encountered. Contexts for communication, in this sense, refer to the four modes of communication derived from the Nonaka theory of knowledge creation as described in Section 2.2 above.

Results were also analyzed using frequency-weighted modes of communication. This analysis assumed that the more frequently encountered communication modes were more important relative to the associated needs. Frequency weights are determined by dividing the frequency of a particular mode of communication by the sum of all frequencies for the four different communication modes studied.

4.2.1 Factor Analysis of Raw Data

Factor analysis was performed on a subset of the survey questions associated with the relative importance of communication needs in different modes of communication. Results of the factor analysis of the raw data survey responses are summarized in Table 4.1. Two rotated principal factors were selected based on the eigenvalues of the correlated principal factors as shown in Table 4.2. The eigenvalues for the first two factors have a cumulative percentage of 50.3%. The cumulative percentage is a measure of the richness of information based on multivariate correlation that is contained within the two selected principal factors.

The rotated factors are indicative of two fundamental groupings of needs characterized as follows:

User Friendliness – A grouping of needs consisting of Ease-of-Use, Ability-to-Organize and Reliability-and-Service. This factor also is highly correlated with Feedback needs for the To-Tacit modes (E2T and T2T).

Privacy – This group of associated needs includes the Ability-to-Personalize and Privacy.

It is important to note that, while Feedback was correlated for the To-Tacit modes of communication, the correlation for To-Explicit modes is not as significant. This implies that the need for feedback in communication is important in situations where the sender attempts to instill tacit knowledge on the part of the receiver. The need for such feedback is associated with the context of the overall User Friendliness of the medium. Since the need for feedback appears to be context specific, subsequent analysis of the utility of media in Section 4.5 will treat the need for Feedback as a separate "factor" apart from User Friendliness.

Table 4.1: Factor Analysis of Needs for Modes of Communication (Raw Data)

Mode/Need	Factor 1	Critical Need	Note	Factor 2	Critical Need	Note
T2E Ease	0.85	X	Ease of Use	-0.15		
T2E Person	-0.24			0.69	X	Personalize
T2E Feedback	0.17			0.04		
T2E Security	0.49			0.70	X	Security
T2E Organize	0.64	X	Organize	0.26		
T2E Service	0.58	X	Service	0.20		
T2T Ease	0.81	X	Ease of Use	0.04		
T2T Person	0.02			0.74	X	Personalize
T2T Feedback	0.63	X	T2T Feedback	-0.10		
T2T Security	0.33			0.72	X	Security
T2T Organize	0.63	X	Organize	0.31		
T2T Service	0.64	X	Service	0.28		
E2T Ease	0.73	X	Ease of Use	-0.11		
E2T Person	0.02			0.61	X	Personalize
E2T Feedback	0.51	X	E2T Feedback	0.11		
E2T Security	0.23			0.71	X	Security
E2T Organize	0.67	X	Organize	0.36		
E2T Service	0.55	X	Service	0.49		
E2E Ease	0.82	X	Ease of Use	0.01		
E2E Person	0.10			0.82	X	Personalize
E2E Feedback	0.48			0.39		
E2E Security	0.12			0.64	X	Security
E2E Organize	0.55	X	Organize	0.09		
E2E Service	0.77	X	Service	0.25		

Note on Factor Analysis:
Factor 1 is a grouping of Needs that reflects how **User Friendly** communication is perceived
Factor 2 is a grouping of Needs reflecting the **Privacy** communication offers.

Table 4.2: Factor Correlation Eigenvalue Summary

Factor	Eigenvalue	Percent	Cumulative Percent
1	8.50	35.4%	35.4%
2	3.57	14.9%	50.3%
3	2.32	9.7%	60.0%
4	2.00	8.4%	68.3%
5	1.61	6.7%	75.0%

4.2.2 Population Segmentation Correlation to Factored Needs

The rotated principal factored needs were added as factor scores to the collection of user responses and the correlation with the population segmentation questions was investigated. There was no significant correlation between the segmentation question survey responses and the factored needs. It can be concluded that the likelihood of the respondent adoption of new communication technology (i.e., PDA usage), age or gender are statistically insignificant with respect to the factored needs. In effect, the groups of correlated needs identified by the factor analysis do not vary with respect to age, gender or preference toward adoption of new communication technologies. These needs can be assumed to be independent of such population segments over the entire control population.

4.2.3 Factor Analysis of Frequency-Weighted Results

Results of the factor analysis of the frequency-weighted survey responses are summarized in Table 4.3. Three rotated principal factors were selected based on the eigenvalues of the correlated principal factors in Table 4.4, which indicate that the first three factors have a cumulative percentage of 54.7%.

The results differ from the previous raw data factor correlations. When the frequencies at which the four different modes of communication are encountered are considered, the rotated principal factors are grouped not around common needs, but around the communication modes themselves. These groupings are characterized as follows:

To-Tacit – A grouping of all needs associated with communication modes intended to instill tacit knowledge in the receiver. This includes both the Tacit-to-Tacit and Explicit-to-Tacit modes. Such communication processes are focused on Socialization and Internalization, as discussed in Section 1.2 above.

Explicit-to-Explicit – This grouping of needs reflects a negative correlation with all the Explicit-to-Explicit associated communication needs. The negative correlation values within the rotated factor are a consequence of the direction or orientation of the rotated factor. The fact that all correlation values have the same sign for the Explicit-to-Explicit mode indicates that the frequency-weighted responses are correlated. This correlation can be attributed to the fact that communication of explicit knowledge is relatively easy, since explicit modes of communication are associated with formats have established syntax making such knowledge easy to convey. It should be noted that the real challenge in dealing with explicit information is in searching for data and the challenge of combining different formats. The survey did not consider such scenarios, as it dealt with only the situation where explicit information was considered readily available and required only transmittal to others.

Tacit-to-Explicit – This factor represents a group of needs associated with the Tacit-to-Explicit mode of communication. This mode of communication is characterized by the transformation of tacit knowledge into an espoused metaphor.

Table 4.3: Factor Analysis of Needs for Communication Modes (Frequency-Weighted)

Mode/Need	Factor 1	Note	Factor 2	Note	Factor 3	Note
T2E Ease	0.16		-0.29		0.58	T2E
T2E Person	-0.39		-0.20		0.47	T2E
T2E Feedback	-0.40		-0.09		0.65	T2E
T2E Security	0.10		-0.61		0.40	
T2E Organize	0.23		0.19		0.65	T2E
T2E Service	0.19		-0.02		0.61	T2E
T2T Ease	0.67	To Tacit	-0.01		0.35	
T2T Person	0.14		0.07		0.47	
T2T Feedback	0.03		0.17		0.74	
T2T Security	0.68	To Tacit	-0.11		-0.03	
T2T Organize	0.61	To Tacit	0.26		0.41	
T2T Service	0.71	To Tacit	0.14		0.17	
E2T Ease	0.67	To Tacit	-0.21		0.16	
E2T Person	0.55	To Tacit	-0.03		0.07	
E2T Feedback	0.44		-0.10		0.54	
E2T Security	0.77	To Tacit	0.00		-0.15	
E2T Organize	0.87	To Tacit	-0.04		0.17	
E2T Service	0.85	To Tacit	-0.04		0.08	
E2E Ease	0.45		-0.52	E2E	0.10	
E2E Person	0.00		-0.75	E2E	-0.21	
E2E Feedback	-0.09		-0.88	E2E	-0.10	
E2E Security	-0.08		-0.82	E2E	-0.31	
E2E Organize	0.02		-0.65	E2E	0.16	
E2E Service	0.56		-0.57	E2E	0.13	

Note on Factor Analysis:
Factor 1 is a grouping of Needs that reflects communication modes involving creating Tacit Knowledge within the recipient. (I.e., **To-Tacit)**
Factor 2 is a grouping of Needs reflecting the needs associated with conveying **Explicit-to-Explicit** information. Such communication concerns data that are already formatted to suit a specific syntax.
Factor 3 is a group of Needs reflecting the communication mode of **Tacit-to-Explicit**.

Table 4.4: Factor Correlation Eigenvalue Summary

Factor	Eigenvalue	Percent	Cumulative Percent
1	6.42	26.8%	26.8%
2	3.74	15.6%	42.3%
3	2.97	12.4%	54.7%
4	2.29	9.5%	64.2%
5	1.38	5.7%	70.0%

4.2.4 Correlation of Media Frequency of Use with Factors

Additional factor analysis was performed to compare the factored User Friendly and Privacy needs of Section 4.2.1 with the frequency of media use. Results of the correlation are summarized in Table 4.5. This table summarizes the correlation of the responses to survey questions wherein subjects were asked how often they used specific media with the factored communication needs. Such correlations to factored needs can be studied once the factor scores have been assigned to each respondent. Factor scores reflect the degree of correlation of each respondent with regard to their individual responses to survey questions related to the set of needs summarized by the factors. Pager frequency was omitted, since over half the respondents indicated that they did not use pagers.

E-Mail showed a zero correlation with factored need. This is a consequence of the fact that every respondent indicated that they used E-Mail on a daily basis, which was the highest frequency-rating category. E-Mail is generally used on a much higher frequency such that future surveys should categorize the frequency of E-Mail use in terms of the number of correspondences per day.

Other observations include the fact that the User Friendliness factor was correlated with the frequency of use of Voice, Shared (Web) Documents and Fax media. Privacy, on the other hand, was correlated with Face-to-Face and Video media frequency of use.

Due to the limitations in the data for E-Mail and Pager media, the correlation with media frequency of use was not performed for the communication mode frequency-weighted data sample.

Based on the correlations, respondents with a preference for needs associated with the User Friendliness of media also used Voice, Shared Documents and Fax on a more frequent basis. Subsequent media utility analysis in Section 4.2.7 also showed that these media also ranked relatively high with regard to the User Friendliness need factor as shown in Figure 4.8.

Privacy was correlated with Face-to-Face and Video media, indicating that respondents who used such media also appreciated the ability of such media to support the need for secure, confidential communication. These media also ranked highest in both the Privacy and Feedback factor utilities (See Figures 4.7 and 4.9).

Based upon the correlation of frequency of use with the factors and the corresponding utilities of media, respondents have a tendency to select and use media that satisfy their preferences for specific communication needs.

Table 4.5: Correlation of User Friendly and Privacy Factors with Media Frequency

	Rotated Factors	
	Factor 1	**Factor 2**
Email Freq	0.00	0.00
Video Freq	0.35	-0.60
F2F Freq	-0.08	-0.71
Voice Freq	0.70	-0.04
Web Freq	0.58	-0.30
Fax Freq	0.70	0.16
User Friendly	0.55	-0.20
Privacy	0.12	-0.85

Note: Eigenvectors associated with the Rotated Factors represent Cumulative Percent of 43.8%

4.2.5 Cluster Analysis of Raw Data Factor Correlation

Cluster analysis of the raw data sample showed four distinct segments, as shown in the dendogram in Figure 4.1. A dendogran shows the tree structure of the clusters that exist in the survey population. Respondents on the same branch of the tree share similar preferences. For example, one cluster consists of respondents 1, 14, 27, 12, 22, and 32. The tree structure also shows how the clusters are further segregated into sub-clusters of respondents with similar preferences. For example, respondents 22 and 32 are closely grouped at a lower level, indicating that their responses were generally very consistent with each other.

At the bottom of the dendogram is a chart that shows the percent of overall correlation differences that are captured with different levels of clustering. Using the dendogram, we can divide the group into as many clusters as desired, up to a maximum of one respondent per cluster. Beginning with a single cluster consisting of the entire population of respondents, we divide the sample group into clusters by following the branches in the tree

structure. Each subsequent partitioning of clusters results in the creation of another cluster that is somehow different than the other clusters in the prior level of partitioning. However, as the partitioning proceeds, the process reaches a point where newly created clusters are not much different from existing clusters at the preceding level. For example, there is a significant drop in the curve between the second and third partitioning, and an additional drop in the curve after the partitioning from three to four clusters. This change indicates that the added clusters are in fact significantly different in their preferences. However subsequent segregation of clusters in going from the fourth to the fifth level of partitioning results in the addition of a cluster that is not much different from one of the four clusters that existed at the fourth level of partitioning as evidenced by the small change in the curve. Therefore, only four clusters are significant. Furthermore, the smallest cluster, consisting of only three respondents identified by the numbers 4, 18 and 11, is associated with surveys that were not filled out completely for all modes of communication and are therefore ignored in further cluster analysis.

The three clusters were plotted against the User Friendly and Privacy factors to illustrate the segmentation, as shown in the perceptual map in Figure 4.2. The segments are labeled according to phrases that reflect the relative preferences with regard to both factors.

One cluster, identified by the phrase "Leave my stuff alone!" reflects respondents who favored privacy as the dominant need. This group represents individuals with shared preferences for the factored need of Privacy that includes the Ability-to-Personalize and Security of the message. This group prefers Privacy to the need for User Friendliness.

A second cluster that is labeled by the statement "Ease of Ownership!" is a collection of respondents who predominantly favor needs associated with the User Friendly rotated principal factor. This group is places greater emphasis on the needs associated with the User Friendliness factor including Ease-of-Use, Ability-to-Organize and Reliability-and-Service. This group is likely to sacrifice some elements of the Privacy need when selecting media that are perceived as more User Friendly.

The third cluster appears to be a group of people with no significant preference for either of the factors associated with User Friendliness or Privacy as indicated by the label: "I don't care!" This third group may represent apathetic users that have come to accept the degree to which media satisfies either need, or that are generally dissatisfied with how well media satisfies both of the two major groups of needs as indicated by the principal factors.

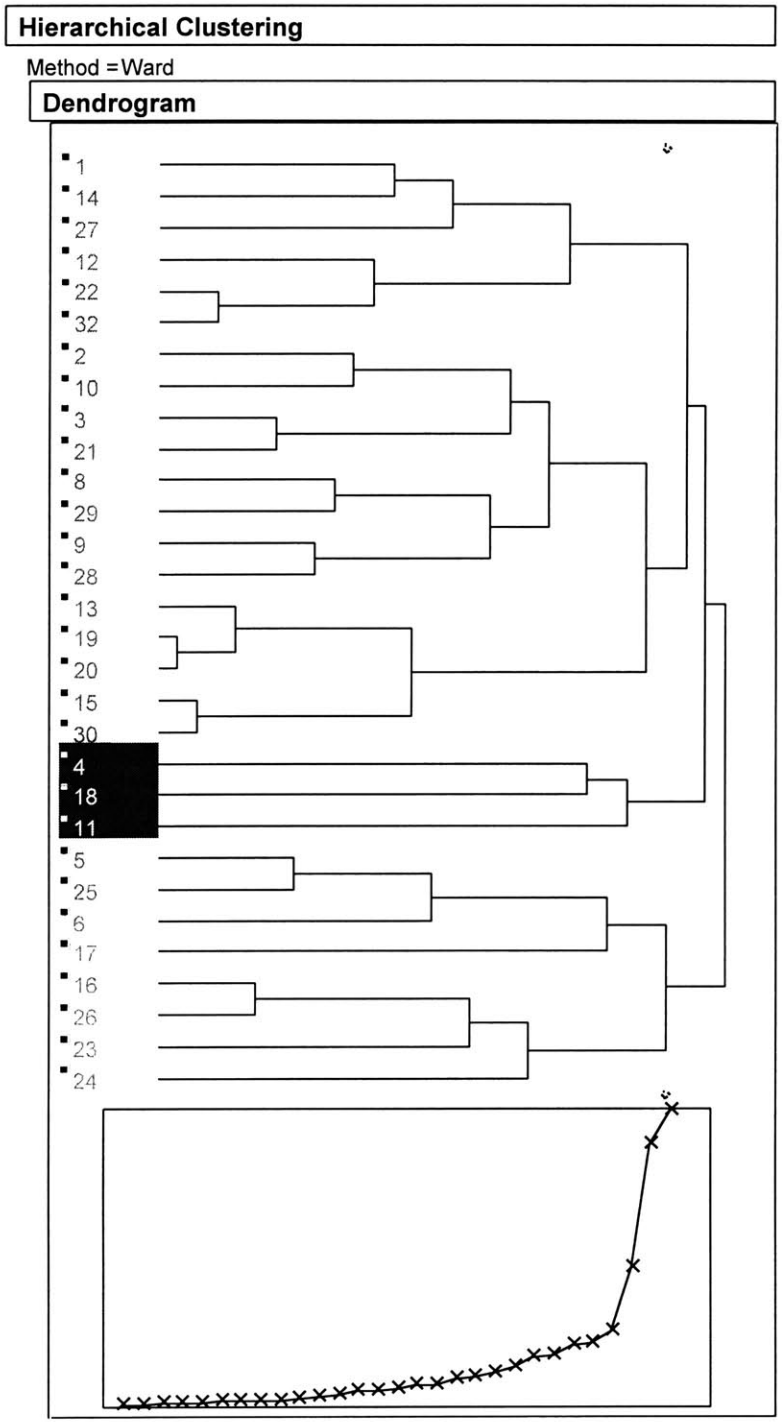

Figure 4.1: Cluster Analysis Dendogram for Raw Data Factor Analysis

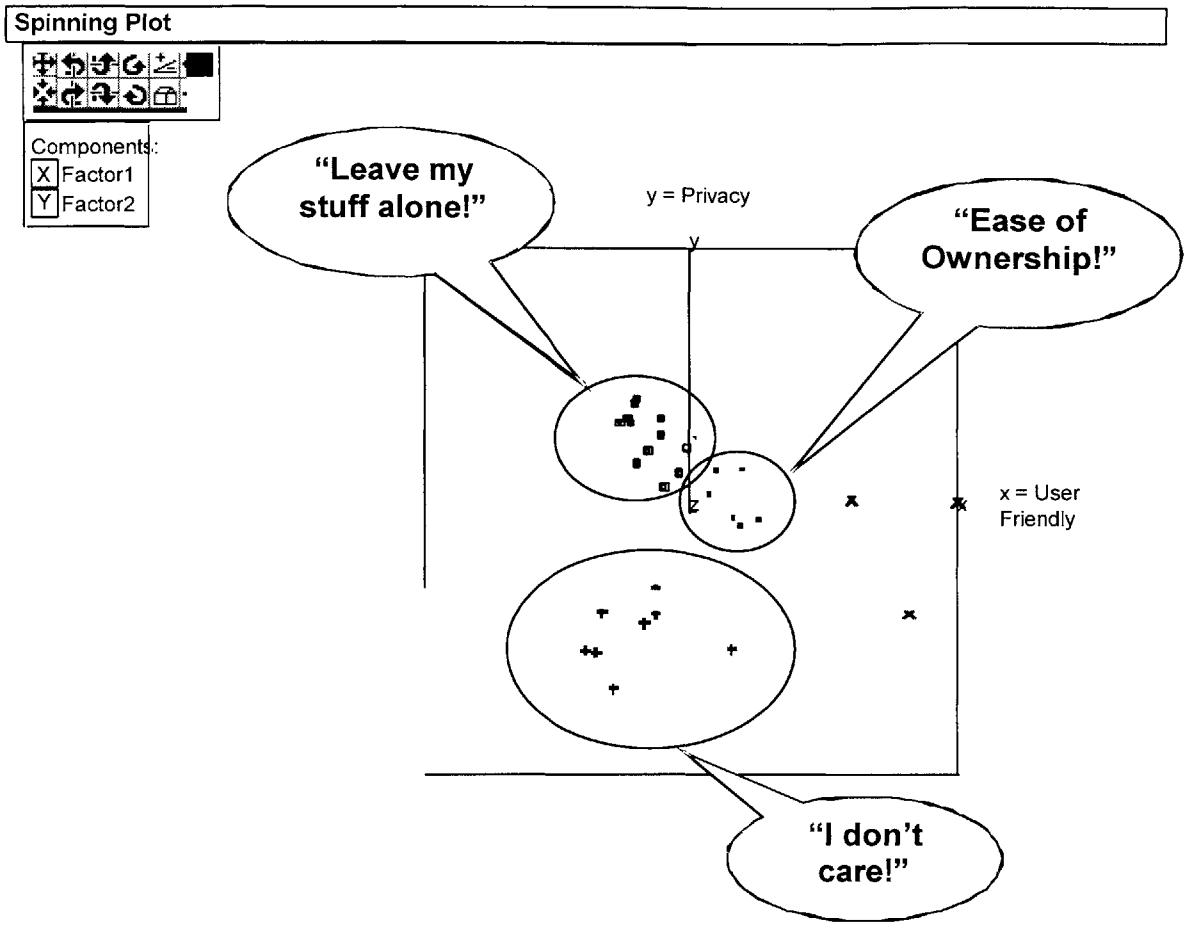

Figure 4.2 Perceptual Mapping of Clusters of Respondents for Raw Data Sample

4.2.6 Cluster Analysis of Frequency-Weighted Factor Correlation

The frequency-weighted factor analysis was used to generate the dendogram in Figure 4.3. It can be observed that frequency-weighted data also reveal the presence of four segments. As with the raw data sample, one of the clusters containing two respondents was omitted from further analysis due to the incompleteness of survey responses from these individuals. The remaining clusters were then plotted into a perceptual map in order to characterize the distinct segments.

Several spinning plots were investigated to show the perceptual mapping of population segments of respondents. The different spinning plots use different views based on the factors chosen as the axes of the plot. The perceptual map that was found to be of most interest is that shown in Figure 4.4, where three distinct clusters are shown relative to the axes of Tacit-to-Explicit and the To-Tacit rotated principal factors. The three group segments are categorized as follows:

Metaphorically Speaking – This is a group (Explicit-to-Tacit) that has a predominant need associated with conveying tacit knowledge in the form of a metaphor.

Teachers/Learners – The To-Tacit mode is associated with socialization and internalization, both of which are common modes of communication in a training environment.

Librarians – The group that had preferences with regard to the needs correlated with the Explicit-to-Explicit rotated factor discussed in Section 4.2.2. As such, these individuals are focused on the combination and convergence of explicit information. As such, these individuals are focused on aggregating, sorting and processing knowledge that is in a predefined format of syntax. Therefore, these respondents are analogous in function to librarians.

As with the factor analysis, the major distinction between the raw data and frequency-weighted factor and cluster analysis is that, while the raw data sample was clustered around

the communication needs, the resulting frequency-weighted segments were clustered around the modes of communication.

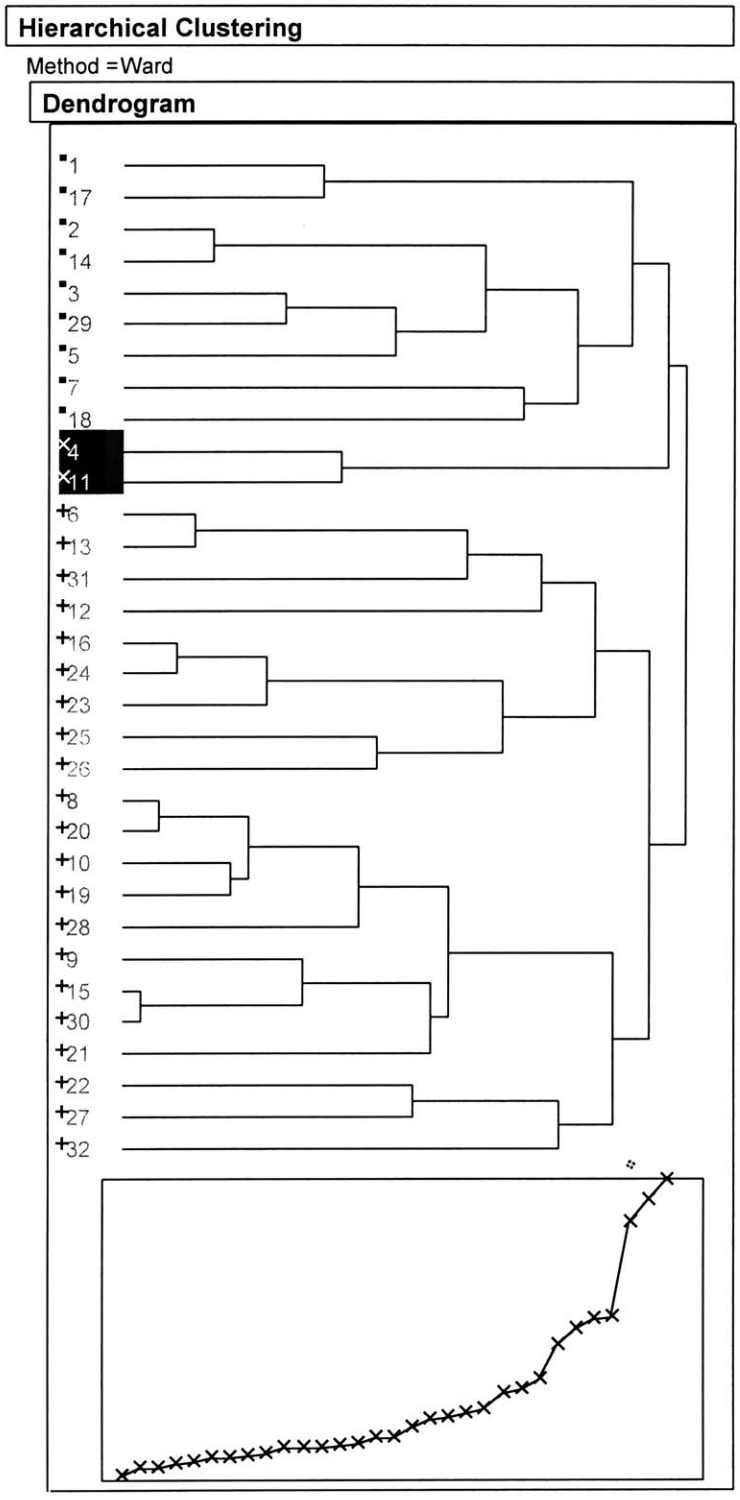

Figure 4.3: Cluster Analysis Dendogram for Frequency-Weighted Data Factor Analysis

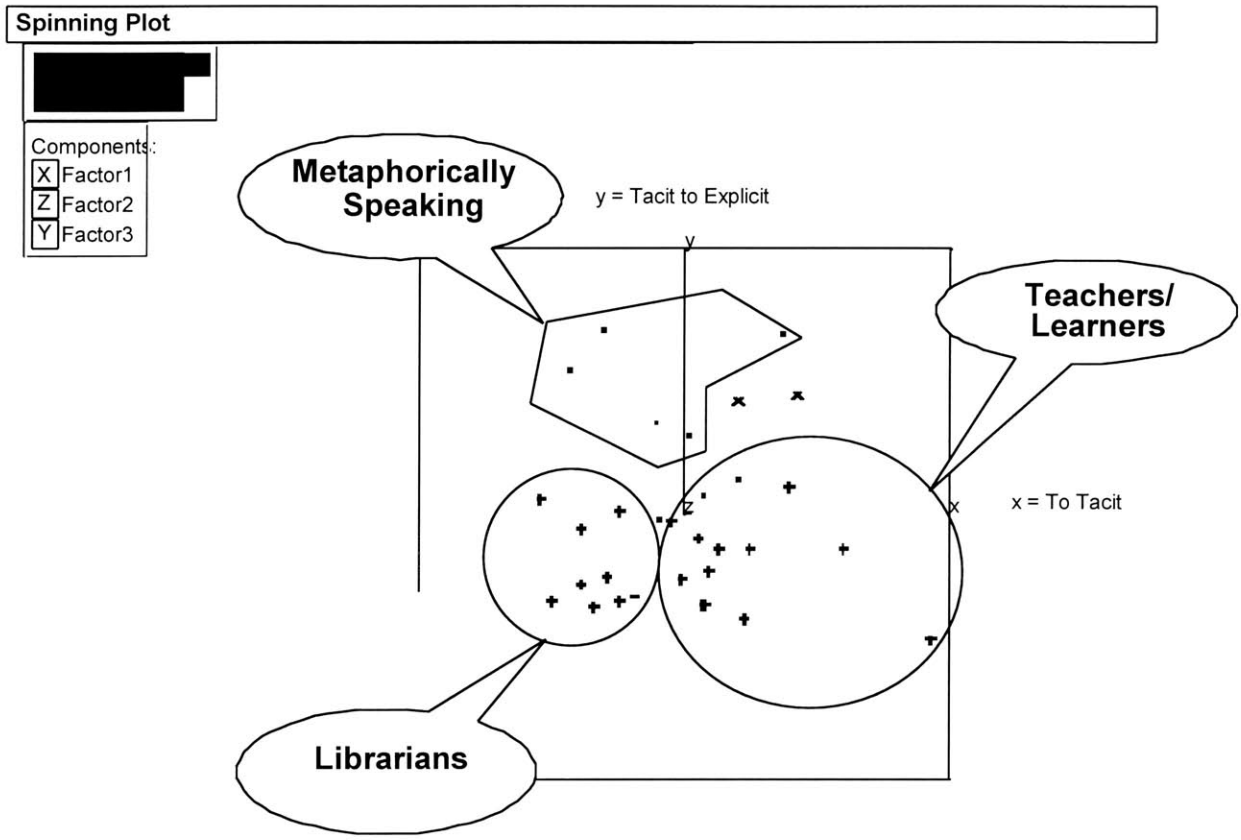

Figure 4.4: Perceptual Map of Clusters of Respondents (Frequency-Weighted)

The significance of the three categories in Figure 4.4 are analogous to the communication needs associated with projects at varying stages of maturity. For example, a new project or technology may be involve significant effort to communicate the vision of the project and associated team-building activities. This is consistent with the needs favored by the Metaphorically Speaking segment. Teachers/Learners may be individuals in the implementation of the early stages of a project concerned with transforming concepts into functional form. Finally, the Librarians could represent individuals in projects that are at a

mature stage where coordination of specific functional activities, information and material are essential tasks to deliver a product in a production environment. Projects at such stages require a greater need to communicate via established reports, data formats and syntax that are generally transmitted in explicit form.

4.2.7 Utility of Media

The utility of media indicates how well a specific communication medium satisfies the collection of communication needs. The ratings of each medium relative to communication needs are combined using a weighting scheme as described in Section 4.1.3. Utilities were calculated for the raw data as shown in Table 4.6. Tables 4.7 and 4.8 show the breakdown of the ratings for needs associated with different modes of communication for both the raw data and frequency-weighted data. The utility of media was not considered for the frequency-weighted data. This is because the utilities of media are computed for predictive purposes, so as to be able to assess the effectiveness of a proposed combination of media. Utilities based on weighted needs using the frequency of encountering different modes of communication are not useful for making such predictions, since, for any randomly selected group of people, the average frequency at which different modes of communication are encountered is generally not known a priori. Furthermore, Figure 4.5 suggests that, with the exception of the Explicit-to-Explicit mode, there is little variation in the relative utility of needs for different communication modes. Therefore, utilities for media are only calculated using raw data samples, for which predictions based on these utilities can be adjusted for frequencies of the modes of communication once such frequencies are known.

Utility of Needs Across Different Modes of Communication

There exists some variation of the relative importance of needs associated with different communication modes. Figure 4.5 shows a plot of the comparison of the relative needs as given by the data in Table 4.7. The most significant variation is associated with the Explicit-to-Explicit mode of communication.

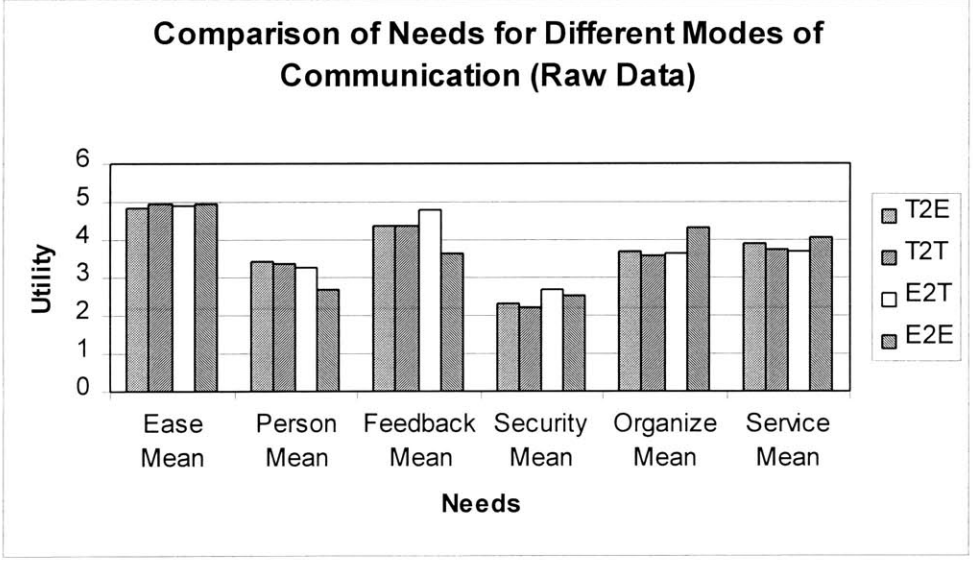

Figure 4.5: Comparison of Needs Across Communication Modes

The dominant need was Ease-of-Use followed by the need for Feedback. It is worth noting that the dominant factor characterized by User Friendliness from Section 4.2.1 consists of the highest utility need of Ease-of-Use combined with the Ability-to-Organize and Reliability-and-Service. Each of these needs was relatively consistently rated for all modes of communication, and all three of the needs ranked higher than the other components of the second Privacy factor consisting of Ability-to-Personalize and Security needs.

While Feedback was not entirely correlated with either of the two principal factors, it is the second most significant need in terms of overall utility. Feedback was also found to be less

important in the Explicit-to-Explicit mode of communication. This observation indicates that there is less need for feedback in communication involving purely explicit information. Since Explicit-to-Explicit formats typically occur in the form of a well-understood syntax, this observation is consistent with the fact purely explicit modes of communication are more concerned with combination and synthesis of different sources of information as opposed to interactive feedback mechanisms associated with the transfer of tacit knowledge. Similarly, the fact that both the need to organize information had a higher utility rating and the need to personalize was lower for the Explicit-to-Explicit mode is also consistent with the E2E combination of information.

Utility Rankings of Media for Different Communication Needs

Utilities of media derived from the raw data sample in Table 4.6 are plotted in Figure 4.6 to show the comparison of how well different media satisfy communication needs. The highest utilities for Ease-of-Use were for Face-to-Face, Voice and E-Mail. Similarly, these media also were ranked highest for Ability-to-Personalize, Feedback and Reliability-and-Service. In the Ability-to-Organize, E-mail was also ranked highly along with Shared Documents (i.e., Web). The only need for which E-Mail was ranked relatively low was Security, where Face-to-Face was the medium of choice for with regard to confidentiality and security of information.

Since there was little difference in the utility ratings for the raw data sample of needs across different modes of communication, with the exception of the Explicit-to-Explicit mode as discussed above, it can be assumed that there are no significant differences in perceived

utility due to the different modes of communication. Therefore, it can be concluded that the utility of any media does not vary significantly with regard to the context.

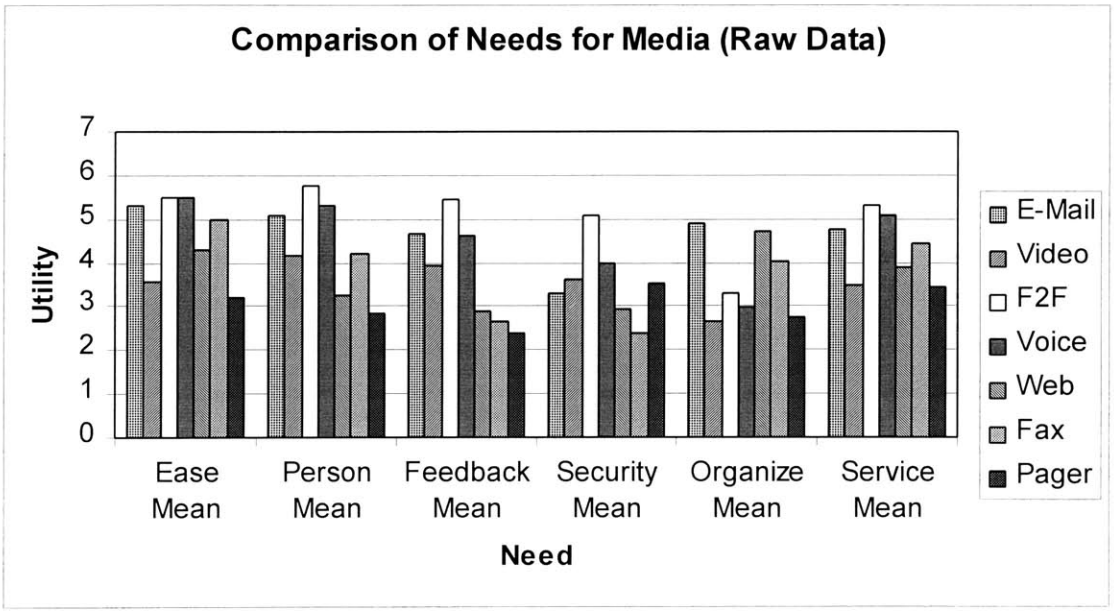

Figure 4.6: Media Utility Rankings for Different Communication Needs

Comparison of Utility of Media for Factors

While the comparison of the utility of media across the different needs is informative, a much better approach is to compare the combined utility of the needs associated with the factors that were significant for overall communication needs. These factors are the User Friendliness and Privacy factors discussed in Section 4.2.1. In evaluating the media according to these factors, we develop a more compact measure of the overall effectiveness of media that is aligned with the preferences of individuals in various segments described in Section 4.2.2.

The Figures 4.7 and 4.8 show the comparison of the utilities of media with respect to specific needs associated with the derived factors representing User Friendliness and Privacy. Since Feedback was not entirely correlated with the factors discussed in Section 4.2.1, it is introduced as a separate "factor" for comparison of media. Feedback utility of the media is shown in Figure 4.9. It is worth noting that Face-to-Face ranked highest on Privacy and Feedback, while E-Mail was perceived as most user friendly. Voice also ranked relatively highly as compared to the factors studied.

4.2.8 Pair-wise Correlations

Pair-wise correlations of the responses to specific survey questions are summarized in Appendix V. The reader is referred to the appendix for highlights of the comparisons. In general, the pair-wise correlations are consistent with the results of more sophisticated analysis methods. It is worth noting that the pair-wise correlations alone would not have yielded the quality of insight as gained from the factor and cluster analysis.

Table 4.6: Utility Calculations for Media Using Raw Data from Survey Responses

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean	Utility	Percent Utility
E-Mail	5.313	5.094	4.667	3.313	4.906	4.774	4.777	79.6%
Video	3.548	4.167	3.929	3.613	2.633	3.500	3.553	59.2%
F2F	5.500	5.774	5.467	5.094	3.281	5.290	5.077	84.6%
Voice	5.469	5.313	4.600	4.000	2.969	5.097	4.633	77.2%
Web	4.281	3.233	2.867	2.906	4.719	3.871	3.715	61.9%
Fax	5.000	4.219	2.667	2.387	4.032	4.419	3.894	64.9%
Pager	3.222	2.842	2.389	3.526	2.765	3.444	3.004	50.1%

Table 4.7: Ratings of Needs for Communication Modes Using Raw Data

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean
T2E	4.844	3.406	4.344	2.313	3.688	3.875
T2T	4.969	3.344	4.375	2.219	3.563	3.719
E2T	4.969	3.375	4.844	2.844	3.719	3.813
E2E	5.000	2.813	3.750	2.688	4.406	4.156
Needs Avg.	4.945	3.234	4.328	2.516	3.844	3.891
Weighted Avg.	0.217	0.142	0.190	0.111	0.169	0.171

Table 4.8: Ratings of Needs for Communication Modes (Frequency-Weighted)

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean
T2E	1.407	0.996	1.240	0.739	1.095	1.168
T2T	1.270	0.817	1.089	0.582	0.895	0.956
E2T	1.074	0.735	1.066	0.575	0.798	0.823
E2E	1.180	0.612	0.801	0.576	1.043	1.013
Needs Avg.	1.233	0.790	1.049	0.618	0.958	0.990
Weighted Avg.	0.219	0.140	0.186	0.110	0.170	0.176

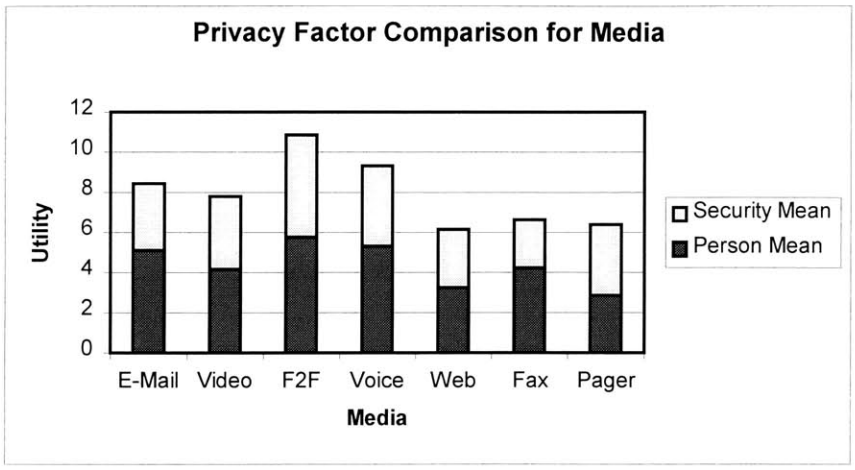

Figure 4.7: Comparison of Media Utility for Privacy Factor

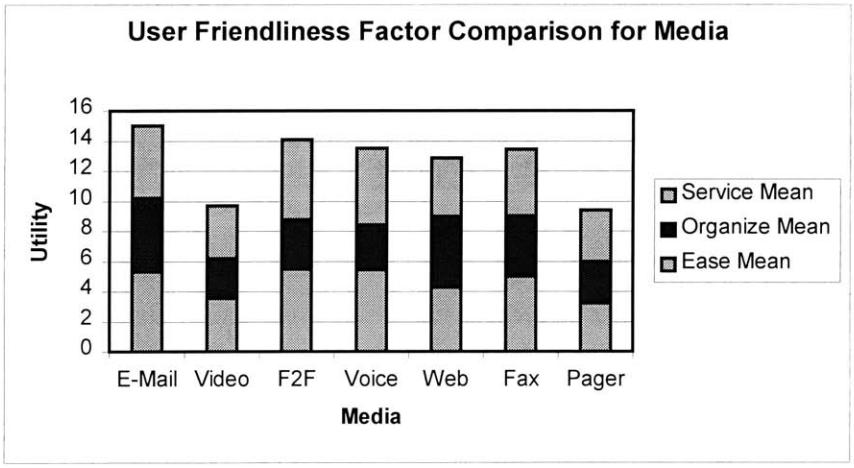

Figure 4.8: Comparison of Media Utility for User Friendliness Factor

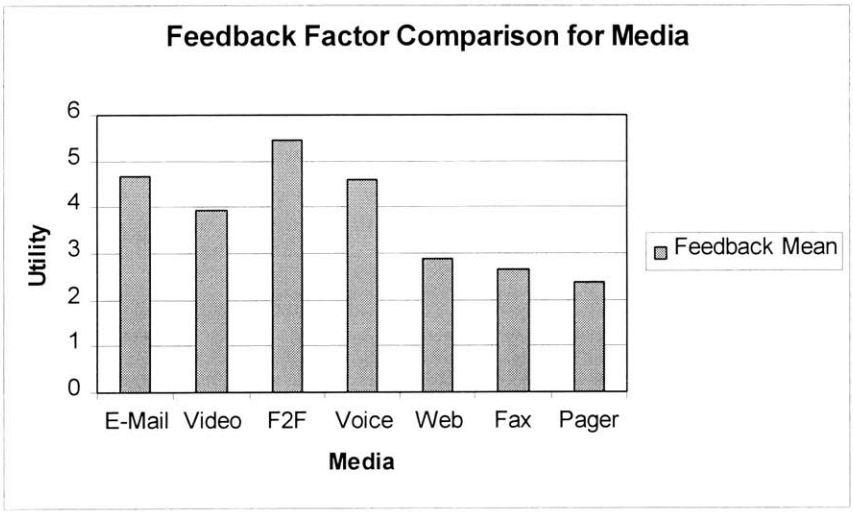

Figure 4.9: Comparison of Media Utility for User Feedback

4.2.9 Summary of Results from Control Survey Data Analysis

Several significant findings from the control survey data were discovered. Factor analysis of the raw data sample identified two basic sets of communication needs important to the selection of appropriate media. These are summarized in Table 4.1 and include:

1. **User Friendliness** – A grouping of needs focused consisting of Ease-of-Use, Ability-to-Organize and Reliability-and-Service.

2. **Privacy** – This group of associated needs includes the Ability-to-Personalize and Security.

While Feedback was partially correlated with the User Friendliness factor for To-Explicit modes of communication, a separate third "factor" was introduced to account for the need related to the ability of media to support feedback. Associated with the factor analysis of raw data were three distinct clusters of respondents. These groups are characterized by the following phrases, as shown in the Figure 4.2,

1. "Leave my stuff alone!" – **Privacy**

2. "Ease of ownership!" – **User Friendliness**

3. "I don't care!" – **Apathy**

When Factor Analysis included responses weighted by frequency at which specific modes of communication were encountered, the dominant factors were related to the modes of communication themselves. Namely,

1. **To-Tacit** – A grouping of all needs associated with communication modes intended to instill tacit knowledge in the receiver. Such communication processes are focused on Socialization and Internalization.

2. **Explicit-to-Explicit** – This grouping of needs is reflects a correlation with all the Explicit-to-Explicit associated communication needs. This correlation can be attributed to the fact that communication of explicit knowledge is relatively easy, and that the survey was limited to situations where explicit information was considered readily available so that costs associated with search and convergence of information was not directly addressed by the survey.

3. **Tacit-to-Explicit** – This factor represents a group of needs associated with the Tacit-to-Explicit mode of communication. This mode of communication is characterized by the transformation of tacit knowledge into an espoused metaphor.

Associated with the factor analysis of frequency-weighted data were also three clusters, as follows (see also Figure 4.4),

1. **Metaphorically Speaking** – Respondents who favored needs associated with the Tacit-to-Explicit mode of communication.

2. **Teachers/Learners** – This group is concerned with the need to instill tacit knowledge in the recipient of information.

3. **Librarians** – These respondents were inclined to

Communication needs did not vary according to the segmentation questions related to the likelihood or disposition to adopt new communication technologies, such as usage of PDA's, gender and age of respondents. Therefore, the communications needs identified are universal with respect to such population segmentation.

The utility preference for individual communication needs is mostly independent of the mode of communication, with the exception of the Explicit-to-Explicit mode. This mode was consistent with a reduced need for Feedback and Personalization and an increased need for the Ability-to-Organize information.

The most effective comparisons for media are based upon the factors resulting from the raw data sample. The highest utility media for each factor are ranked as follows:

Table 4.9: Highest Performing Media Utility Rankings for Factors

User Friendliness	Privacy	Feedback
1. E-Mail 2. Face-to-Face 3. Voice 4. Fax	1. Face-to-Face 2. Voice 3. E-Mail	1. Face-to-Face 2. Voice 3. E-Mail

Based upon the results in Table 4.9, it might be argued that the needs analysis from the survey suggest that a robust communication environment can be achieved using a combination of E-Mail, Voice and Face-to-Face. However, global teams are faced with dispersion is space and time that confounds the utilization of particular media.

Allen (1977) discussed the reduced probability of Face-to-Face conversation as the distance between team members increased. Sosa (1999) further confirmed the results of Allen's research based upon the probability distribution of utilization of Face-to-Face, Voice and E-Mail as a function of separation. Since the probability of Face-to-Face declines dramatically with increased distance of separation (even on the order of only 15 meters) and Voice declines significantly for large distances (5000 km+) where differences in time zones become a factor, E-Mail consequently becomes the default medium of choice for global teams.

Furthermore, the control survey did not consider the effects of the presence of culture and language differences. Therefore, the sample Sponsor Company survey was designed and administered to capture the effects upon the communication needs of respondents when considering situations where global dispersion and other barriers to communication introduced by culture and language differences were involved.

4.3 Sample (Sponsor Company) Population Survey Results

In performing the analysis of the survey data, results were first compared using the raw data as provided by the respondents. The analysis of raw data assumes that there is no difference in relative importance as indicated by the frequency at which different contexts of communication were encountered. Contexts for communication, in this sense, refer to the four modes of communication derived from the Nonaka theory of knowledge creation as described in Section 2.2.

Results were also analyzed using frequency-weighted modes of communication. This analysis assumed that the more frequently encountered communication modes were more important relative to the associated needs. Frequency weights are determined by dividing the frequency of a particular mode of communication by the sum of all frequencies for the four different communication modes studied.

4.3.1 Factor Analysis of Raw Data

As with the control survey, the sample survey responses from the Sponsor Company were analyzed for factors using the subset of the survey questions associated with the relative importance of communication needs in different modes of communication. Results of the factor analysis of the raw data survey responses are summarized in Table 4.10. Three rotated principal factors were selected based on the eigenvalues of the correlated principal factors as shown in Table 4.11. The eigenvalues for the first three factors have a cumulative percentage of 62.4%. This cumulative percentage indicates that these three factors contain over 60% of the correlation information from the entire subset of survey questions used in the factor analysis.

The rotated factors are indicative of three fundamental groupings of needs characterized as follows:

Organization vs. Security – A grouping of needs associated with the trade-off of needs to support the ability to organize information or security.

Ease-of-Use/Service vs. Ability-to-Personalize – A grouping of needs focused consisting of Ease-of-Use and Reliability-and-Service. This factor was also negatively correlated with the need for the Ability-to-Personalize the message.

Feedback – This group of associated needs includes the Feedback capabilities of media. This factor was correlated for all modes of communication with the exception of Explicit-to-Explicit.

The first factor contains represents a separation of the need for media to support the Ability-to-Organize from the User Friendliness factor. This factor is also negatively correlated with the need for Security. The negative correlation implies that respondents who favored the Ability-to-Organize did not prefer Security and those that desired Security did not care for the capabilities of media to support the organization of information. Essentially, this is a trade-off between structure and security of information.

One plausible explanation for this correlation is that the sample survey population consists entirely of personnel within the Sponsor Company that conduct business using the corporate intranet and internal, secure computer networks. Thus, it is likely that the need for security of information is taken for granted as part of the overall communication environment. This is

in contrast to the control survey respondents that were surveyed about their needs in the context of generic communication environments with public Internet service providers. Concerns over the security within the World Wide Web also were raised as part of the interview process. Therefore, if the Ability-to-Organize has a higher utility relative to Security, we can conclude that the first factor is in fact primarily concerned with the need to organize information and is negatively correlated with the need for security only as an artifact of the existing corporate network.

Alternatively, the respondents may be highly conscious of the need for appropriate security precautions in the communication environment to ensure that the confidential information within the corporation will not be compromised. This may be true for both external communications where the concern is that competitors will obtain company information as well as for internal communication relative to the need to maintain confidentiality of sensitive personnel data such as individual performance assessments and compensation. A consequence of the negative correlation with the Ability-to-Organize indicates that respondents are willing to sacrifice this need in order to preserve Security. This hypothesis can be also confirmed by a high utility for the need for Security relative to organization of information.

A third possibility is that two primary, distinct clusters of respondents exist associated with both viewpoints above. This is best investigated using cluster analysis where the respondents are plotted relative to their preferences against axis dimensions representing the grouping of needs associated with the rotated principal factors derived from factor analysis.

The second factor is somewhat consistent with the User Friendliness factor in the control survey population (Section 4.2.1), except that users are likely to sacrifice the ability to personalize information in order to enjoy Ease-of-Use and Reliability-and-Service. As with the trade-off discussed between needs in the first factor, the trade-off between the Ease-of-Use and Reliability-and-Service needs with the Ability-to-Personalize will be investigated in subsequent analysis to refine the interpretation of results.

Finally, in contrast with the control survey results, Feedback is a correlated principal factor with the Sponsor Company survey population as indicated by the third factor. Further analysis will be performed as with the control population responses, where the need for Feedback was treated as if it were a separate "factor" in the analysis of the control survey population.

In summary, the factor analysis of the Sponsor Company sample survey population revealed groupings of needs associated with trade-offs of needs for the first two factors. As a result, cluster analysis will be concerned with unraveling the confounding preferences of individuals for the needs associated with the factors. As discussed above, the internal corporate environment includes an added element of concern for security of information. The concern for security is both heightened and simultaneously mitigated by the presence of a perceived secure corporate network and the added element of trust associated with the fact that all members are part of the same company.

Heightened awareness of security concerns arises from the competitive pressures of the business environment and by the need to separate Sponsor Company corporate e-mail and other internal databases from the parent Company as part of the recent spin-off. Similarly,

the very presence of a secure network and communication environment can give some respondents a perception that security is not a critical issue, but that it is already addressed by the precautions in place.

In any event, the consequence of making trade-offs among needs in the factors from the Sponsor Company survey population must be unraveled prior to computing combined utilities of media. This is necessary in order to combine utilities for media associated with correlated groupings of needs, i.e., a factor. It makes little sense to combine both positively and negatively correlated needs into one combined factor when computing overall media utilities. One solution to resolve the trade-offs in the utility analysis is to regroup the factored needs according to the factors derived from the control population as shown in Figures 4.7 through 4.9. Another method for regrouping needs to resolve the trade-off issue is to split factors containing both positively and negatively correlated needs into two separate factors. The method for resolving the trade-offs prior to utility analysis will be based in part upon the results of cluster analysis

Table 4.10: Factor Analysis of Needs for Modes of Communication (Sample Population)

Mode/Need	Factor 1	Note	Factor 2	Note	Factor 3	Note
T2E Ease	-0.19		0.38		-0.08	
T2E Person	-0.14		-0.74	Anti-Person	0.06	
T2E Feedback	0.30		-0.01		0.75	Feedback
T2E Security	0.79	Security	-0.12		-0.50	
T2E Organize	-0.74	Anti-Organize	0.00		-0.29	
T2E Service	-0.10		0.74	Service	0.13	
T2T Ease	0.26		0.57	Ease of Use	-0.16	
T2T Person	-0.25		-0.68	Anti-Person	-0.09	
T2T Feedback	-0.01		-0.02		0.77	Feedback
T2T Security	0.87	Security	0.10		-0.09	
T2T Organize	-0.68	Anti-Organize	-0.29		-0.23	
T2T Service	0.06		0.78	Service	-0.12	
E2T Ease	-0.28		0.49	Ease of Use	-0.37	
E2T Person	0.04		-0.67	Anti-Person	0.22	
E2T Feedback	-0.14		-0.34		0.83	Feedback
E2T Security	0.89	Security	-0.07		-0.16	
E2T Organize	-0.84	Anti-Organize	-0.03		-0.25	
E2T Service	0.39		0.67	Service	-0.17	
E2E Ease	-0.24		0.68	Ease of Use	-0.15	
E2E Person	0.10		-0.70	Anti-Person	-0.44	
E2E Feedback	0.50		-0.48		-0.36	
E2E Security	0.73	Security	-0.10		0.28	
E2E Organize	-0.87	Anti-Organize	0.04		0.29	
E2E Service	-0.10		0.69	Service	0.36	

Note on Factor Analysis:
Factor 1 is a grouping of Needs that reflects the level of **Security** of information in communication.
Factor 2 is a grouping of Needs reflecting the **User Friendliness** communication offers.
Factor 3 is a grouping of Needs associated with **Personalization** that communication offers.

Table 4.11: Sample Population Factor Correlation Eigenvalue Summary

Eigenvalue	Percent	Cumulative Percent
6.07	25.3%	25.3%
5.68	23.7%	48.9%
3.23	13.5%	62.4%
2.80	11.7%	74.0%
1.80	7.5%	81.6%

4.3.2 Cluster Analysis of Raw Data Factor Correlation

Cluster analysis of the raw data sample showed four distinct segments, as shown in the dendogram in Figure 4.9. In order to interpret and label the clusters representing groupings of preferences for communication needs, the rotated principal factors derived from the factor analysis (Section 4.3.1) were used to develop perceptual maps. Several spinning plots were investigated as candidates for useful perceptual mappings using combinations of the rotated principal factor scores as dimensions for the axes. The most insightful perceptual maps are shown in Figures 4.10 and 4.11.

Figure 4.10 shows the distribution of clusters when plotted against the axes of the factor representing a trade-off of needs associated with Organize/Security and the factor associated with the trade-off between in Ease-of-Use/Service and the Ability-to-Personalize. Three significant clusters emerge in this perceptual mapping. One cluster is associated with preferences for the needs of Ease-of-Use, Reliability-and-Service and the Ability-to-Organize. These three needs were equivalent to the correlation of needs in the factor analysis of the control sample in Section 4.2.1 identified as the User Friendliness factor. The second group in Figure 4.10, labeled as "Simplicity and Safety", represents respondents that

preferred a mix of needs associated with Ease-of-Use, Reliability-and-Service and Security. This group shares many preferences for communication needs in common with the User Friendliness group, except that the needs are confounded by concerns over security.

The third, largest cluster – "Personal Touch" – represents a group of respondents that felt that the need to convey more personalized messages is critical. In the control sample, this group has needs that are aligned with the cluster associated with the need for Privacy, except that the concerns related to security are not correlated. One plausible explanation for the lack of correlation with the need for security is that respondents favoring the need to personalize messages did not feel threatened by a lack of security due to a perceived higher level of trust and respect for the integrity of information within the corporate communication environment. Since the need for Security was not correlated with the needs preferences within this group of respondents, correlations of Security with the needs of the smaller clusters dominated the factor analysis. Therefore, to resolve the confounding of negatively correlated needs in the factor analysis of the Sponsor Company survey population, the grouping of needs from the control population (User Friendliness, Privacy and Feedback) will be used in subsequent media utility comparisons.

Figure 4.11 uses the factor representing the trade-off between in Ease-of-Use/Service and the Ability-to-Personalize and Personalization factor dimensions to display an alternative view of the clusters of respondents. This view shows the clear delineation of clusters associated identified by the factored needs for "Simplicity and Safety" and "Personal Touch". Furthermore, the group associated with User Friendliness in Figure 4.10 are intermixed with the Simplicity and Safety group, reinforcing the argument that these individuals are

predisposed to common preferences for needs, thereby validating further the assumption that the User Friendliness factor from the control group can be ascribed as a more logical grouping of positively correlated needs in subsequent media utility analysis.

The fourth cluster – "Feedback is the Least of My Concerns!" – consists of only two respondents. This pair showed a decreased concern for the need feedback while, as discussed with regard to the perceptual map in Figure 4.10, had equal preferences for the other dimensions of factored needs. In responding to the questions regarding frequency of encountering different modes of communication, both of these respondents indicated a greater involvement with communication modes involving explicit information. From the control survey population, the dominance of communication modes involving explicit forms of knowledge is consistent with a reduced need for feedback for these respondents.

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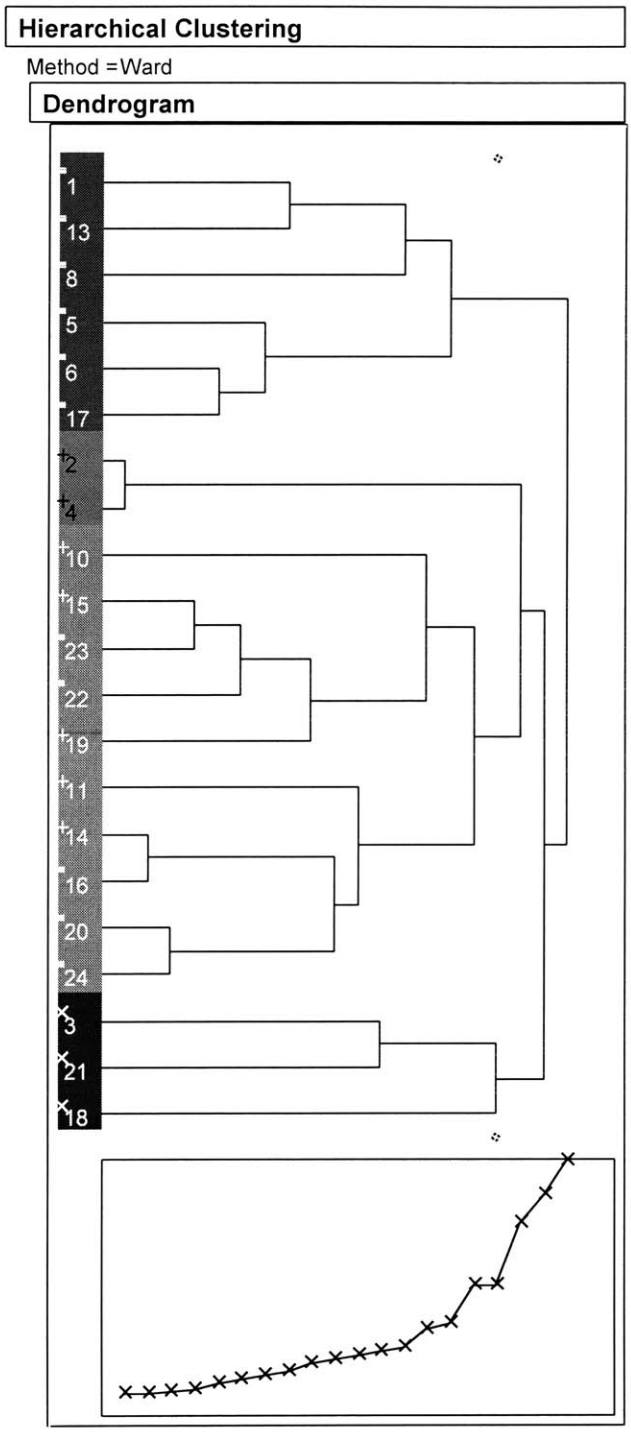

Figure 4.9: Cluster Analysis Dendogram for Raw Data Factor Analysis

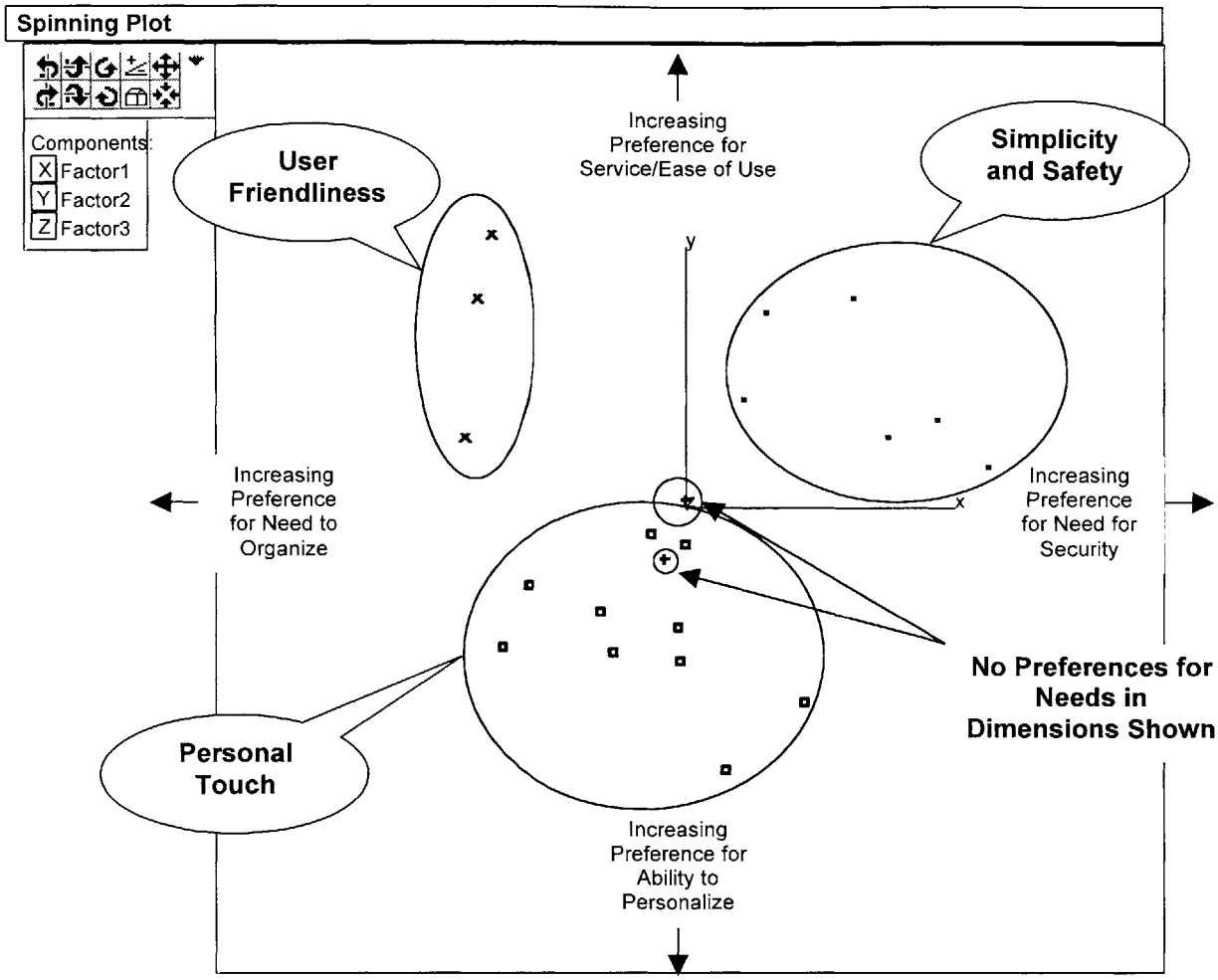

Figure 4.10 Perceptual Mapping of Clusters of Respondents for Raw Data Sample

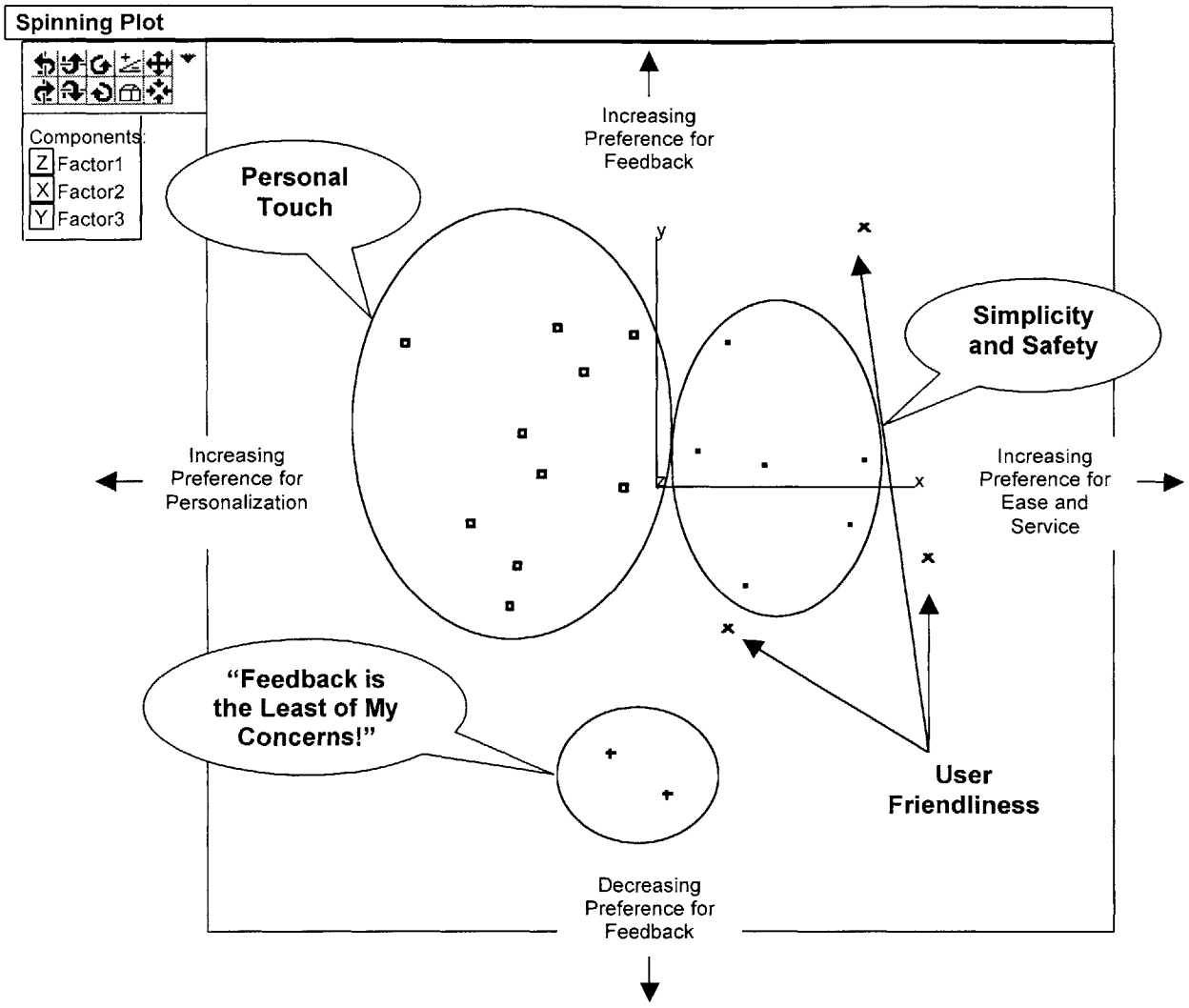

Figure 4.11 Alternative Perceptual Map of Respondents for Raw Data Sample

4.3.3 Utility of Media

The utility of media indicates how well they satisfy the collection of communication needs. Since the correlation of needs in the factors in the Sponsor Company responses were confounded with trade-offs among negatively correlated individual needs, the factors of User Friendliness, Privacy and Feedback derived in the analysis of the control population survey are used in comparing media utilities across factors. The utility ratings of each medium relative to communication needs are combined using the same weighting method as described in Section 4.1.3. Utilities were generated for the raw data as shown in Table 4.7. Tables 4.8 and 4.9 show the breakdown of the ratings for needs associated with different modes of communication for both the raw data and frequency-weighted data. As discussed in Section 4.2.7, the utility of media was not computed for the frequency weighted sample, since the utilities are used for predictive purposes and frequency at which different modes of communication are encountered are not generally known a priori.

Utility of Needs Across Different Modes of Communication

From the analysis of the control survey sample population data, Figure 4.5 (Section 4.2.7) shows the variation of the relative utility of needs across different modes of communication. This can be compared to Figure 4.12, which includes a similar breakdown of needs across different communication modes for the sample Sponsor Company population. Differences between the two figures capture variations in preferences between the two populations when encountering different modes of communication.

In general, the figures indicate that the Sponsor Company population needs preferences are consistent with those of the sample population. Ease-of-Use is the dominant need in both

population segment and does not vary significantly across different communication modes. The Explicit-to-Explicit mode of communication also exhibited the greatest variation in the relative importance of needs. Both populations placed greater importance on the needs for Ability-to-Organize with a corresponding decrease in the need for Feedback and Ability-to-Personalize for the Explicit-to-Explicit mode. One trend that does differentiate the two populations is that Security on the average is equally ranked with respect to the needs associated with the Ability-to-Organize information for all modes. This reflects an increased focus on protecting the security of proprietary company information that was not a factor in the control survey population. Finally, the Tacit-to-Explicit mode of communication had a higher rating for the need of Ability-to-Personalize.

Consistent with the control survey population, the dominant need in the Sponsor Company survey was Ease-of-Use followed by the need for Feedback. In using the control survey principal factor characterized by User Friendliness from Section 4.2.1, it remains consistent with the overall higher utility of Ease-of-Use combined with the Ability-to-Organize and Reliability-and-Service. One difference is that the second principal factor associated with the Privacy factor is that the relative importance of Security and Ability-to-Personalize were both somewhat higher for the Sponsor Company population than was observed in the control survey sample population.

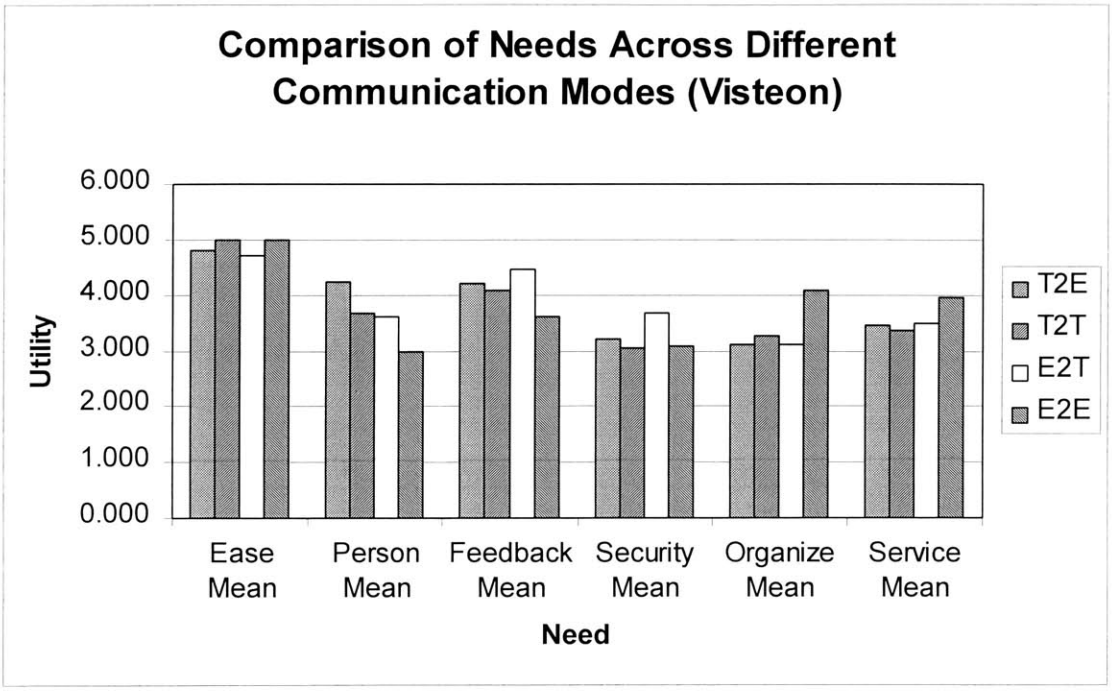

Figure 4.12: Comparison of Needs Across Communication Modes

As with the control survey population, Feedback was not entirely correlated with either of the two principal factors, and it remained the second most significant need in terms of overall utility. Feedback was also found to be less important in the Explicit-to-Explicit mode of communication. This observation confirms that there is less need for feedback in communication involving purely explicit information, since Explicit-to-Explicit formats typically occur in the form of a well-understood syntax. Similarly, the fact that both the need to organize information had a higher utility rating and the need to personalize was lower for the Explicit-to-Explicit mode is also consistent with the E2E combination of information as discussed in Section 4.2.7.

Utility Rankings of Media for Different Communication Needs

Utilities of media derived from the sample Sponsor Company population are shown in Table 4.12 and are plotted in Figure 4.13 to show the comparison of how well different media

satisfy communication needs. Consistent with the control survey population, the highest utilities for Ease-of-Use were for Face-to-Face, Voice and E-Mail. Similarly, these media also were ranked highest for Ability-to-Personalize, Feedback and Reliability-and-Service. In the Ability-to-Organize, E-mail was also ranked highest. The only need for which E-Mail was ranked relatively low was Security, where Face-to-Face was the medium of choice for with regard to confidentiality and security of information. All of these observations are consistent with the findings of the control survey population. The only significant difference was that the media utility ratings for Face-to-Face and Voice were significantly higher for the Ability-to-Organize as compared to the control survey population. This is likely due to the presence of a corporate standard internal scheduling and address within the Sponsor Company, improving the ability to schedule meetings and locate contacts within the corporate environment.

With the significant agreement of relatively small differences in the utility ratings between the control survey population and the Sponsor Company sample population with regard to the needs across different modes of communication, with the exception of the Explicit-to-Explicit mode as discussed above, it can be assumed that there are no significant differences in perceived utility of individual media due to the different modes of communication. Therefore, it can be concluded that the most significant variation in utility generally occurs due to the selection of different media and not with respect to how those media are employed in any specific context.

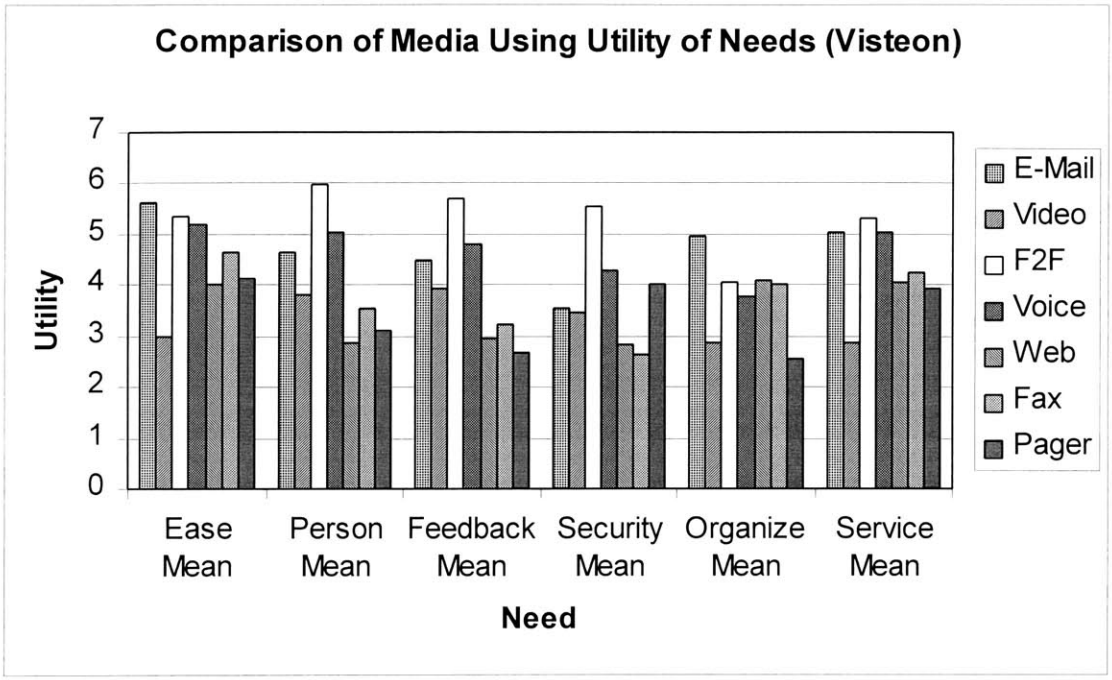

Figure 4.13: Media Utility Rankings for Different Communication Needs

Comparison of Utility of Media for Factors

A better and more insightful approach to interpreting the utility of media in satisfying the needs associated with communication is to use the principal factors that captured significant correlations among the overall set of communication needs. In the analysis of the sample Sponsor Company population, these factors represented trade-offs between various needs in terms of their preferences. These trade-offs were evidenced by the negative correlation of needs preferences in the factors shown in Table 4.10. However, the control survey population exhibited positively correlated factors that included the User Friendliness and Privacy factors discussed in Section 4.2.1.

Since the overall results for the utility of media and the needs across different communication modes were found to be consistent between the two different survey populations, it is

proposed that the evaluation of media according to the grouping of needs in the factors derived for the control survey population are valid for the Sponsor Company sample population. Therefore, we can develop a more compact measure of the overall effectiveness of media within the Sponsor Company population that is aligned with the preferences of individuals in various clusters as described in Section 4.3.2. These clusters, as discussed in Section 4.3.2, include users with preferences that were aligned with the needs grouped in the User Friendliness, Privacy and Feedback factors.

The Figures 4.14 through 4.16 show the comparison of the utilities of media with respect to specific needs associated with the derived factors representing User Friendliness, Privacy and Feedback. These plots can be compared to similar data presented for the control survey population in Figures 4.7 through 4.9. It is interesting to note that the media rankings across these fundamental needs are nearly identical between the two populations. This further justifies the approach of treating the Sponsor Company sample population as exhibiting a similar association and grouping of preferences for communication needs as was found in the control survey population. The grouping of positively correlated needs also helps resolve the negative correlations associated with the trade-offs in the Sponsor Company derived factors. Confidence in this approach is further reinforced when the relative sample sizes of the two survey populations are considered. The control survey consisted of data from over 50% more respondents than in the Sponsor Company survey, thereby improving overall confidence in the results and correlation analysis of the control survey data.

When investigating the relative utility of media across different factored needs as shown in Figures 4.14 through 4.16, the same trends as observed in the control survey data analysis are

observed. Face-to-Face ranked highest on Privacy and Feedback, while E-Mail was perceived as most user friendly. Voice also ranked relatively highly when compared across the factors studied.

Table 4.12: Sponsor Company Media Utilities Using Raw Data from Survey Responses

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean	Utility	Percent Utility
E-Mail	5.625	4.625	4.500	3.542	4.958	5.042	4.777	79.6%
Video	3.000	3.826	3.917	3.458	2.870	2.875	3.322	55.4%
F2F	5.333	5.958	5.708	5.542	4.042	5.292	5.331	88.8%
Voice	5.208	5.043	4.792	4.292	3.792	5.042	4.740	79.0%
Web	4.000	2.864	2.952	2.826	4.091	4.043	3.484	58.1%
Fax	4.625	3.522	3.208	2.625	4.000	4.250	3.759	62.6%
Pager	4.143	3.105	2.667	4.000	2.556	3.947	3.425	57.1%

Table 4.13: Sponsor Company Ratings of Needs for Communication Modes Using Raw Data

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean
T2E	4.792	4.250	4.208	3.208	3.125	3.458
T2T	5.000	3.682	4.091	3.045	3.273	3.364
E2T	4.708	3.625	4.458	3.667	3.125	3.500
E2E	5.000	3.000	3.625	3.083	4.083	3.958
Needs Avg.	4.875	3.639	4.096	3.251	3.402	3.570
Weighted Avg.	0.214	0.159	0.179	0.142	0.149	0.156

Table 4.14: Sponsor Company Ratings of Needs for Communication Modes (Frequency-Weighted)

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean
T2E	1.132	0.973	0.971	0.780	0.717	0.835
T2T	0.967	0.720	0.780	0.599	0.662	0.666
E2T	1.241	1.020	1.226	0.983	0.824	0.914
E2E	1.486	0.905	1.080	0.890	1.194	1.188
Needs Avg.	1.207	0.904	1.014	0.813	0.849	0.901
Weighted Avg.	0.212	0.159	0.178	0.143	0.149	0.158

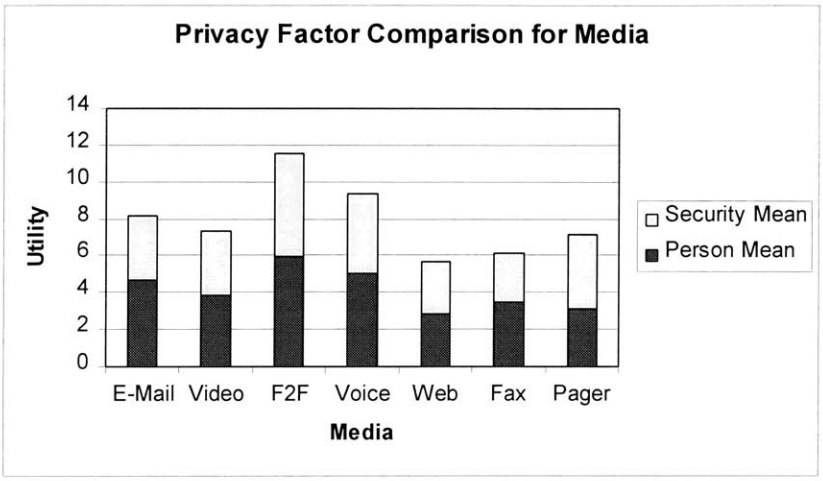

Figure 4.14: Media Utility for Privacy Factor (Sponsor Company Data)

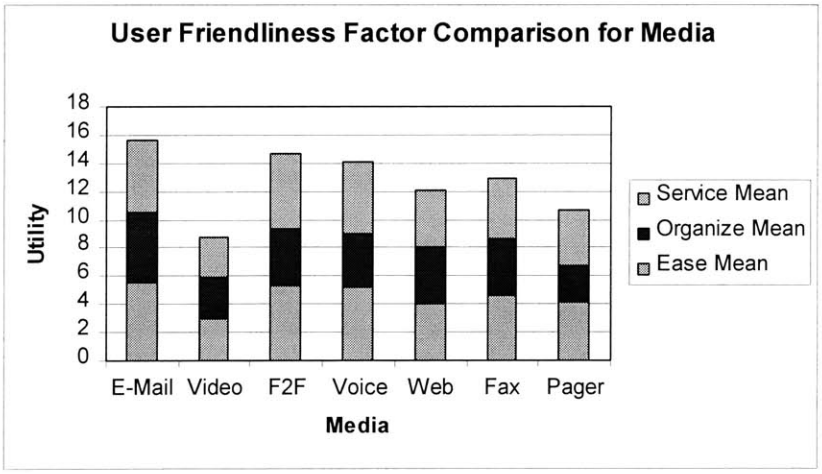

Figure 4.15: Media Utility for User Friendliness Factor (Sponsor Company Data)

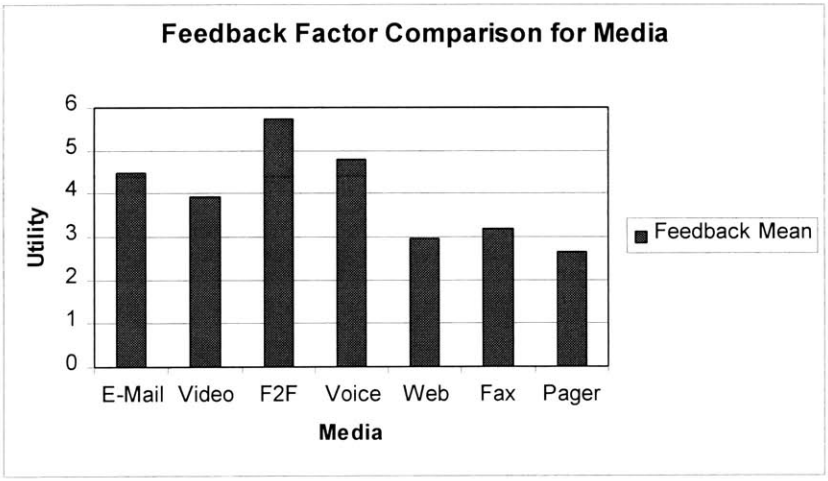

Figure 4.16: Media Utility for Feedback (Sponsor Company Data)

4.3.4 Effects of Culture and Language Barriers (Sponsor Company Data)

In the survey administered to Sponsor Company respondents, questions regarding the effect of the presence of culture and language barriers in communication were asked. The survey was designed such that questions relating to the effect of language barriers were asked prior to questions relating to cultural differences. The order of presenting language and cultural questions was critical, because prior interviews within the Sponsor Company as discussed in Chapter 3 revealed that that people generally considered the effects of culture and language to be a combined overall effect. Therefore, in order to separate the effects of language from culture, questions relating to language were presented before other cultural issues were considered.

Responses to these questions allow for an assessment of how the relative importance of communication needs changes when such communication barriers are encountered. Mean responses to the relative importance of the needs in the presence of language barriers are shown in Table 4.15. Similarly, Table 4.16 shows the relative importance of ranking of the needs when cultural differences are encountered. These needs are ranked on a scale that corresponds to 1 = Least Important to 6 = Most Important. A higher need rating implies a greater importance to the level of satisfaction different media offer with respect to the need. Thus, these ratings can be useful and are applied in modifying the utilities of media to account for changes in needs preferences in the presence of language and cultural barriers.

Table 4.15: Need Ratings with Language Barriers (Sponsor Company)

	Language Ease of Use	Language Ability to Personalize	Language Feedback	Language Security	Language Ability to Organize	Language Reliability and Service
Mean Utility of Need	4.818	4.455	5.682	2.545	4.227	4.136
Need Weight Factor	0.186	0.172	0.220	0.098	0.163	0.160

Table 4.16: Need Ratings with Cultural Barriers (Sponsor Company)

	Language Ease of Use	Language Ability to Personalize	Language Feedback	Language Security	Language Ability to Organize	Language Reliability and Service
Mean Utility of Need	4.182	4.727	5.364	2.682	3.409	3.727
Need Weight Factor	0.174	0.196	0.223	0.111	0.142	0.155

When cultural and language effects are considered in the assessment of the communication needs of respondents in the Sponsor Company sample data survey, changes in the relative importance of needs was observed as shown in Figure 4.17 which compares the original needs preferences within the Sponsor Company population with the modified needs once cultural and language barriers were considered.

Comparison of the results between the original survey responses and those that included language and culture indicate that the utility of Feedback increased significantly to become the most important need as Ease-of-Use, Reliability-and-Service and Ability-to-Organize

(i.e., User Friendliness) became less critical. The utility of Security dropped most dramatically when both language and cultural barriers to communication were considered. The reduced preference for Security indicates that when culture and language barriers are present individuals are likely to accept the increased risk that data are compromised rather than allow satisfaction relative to other communication needs to suffer.

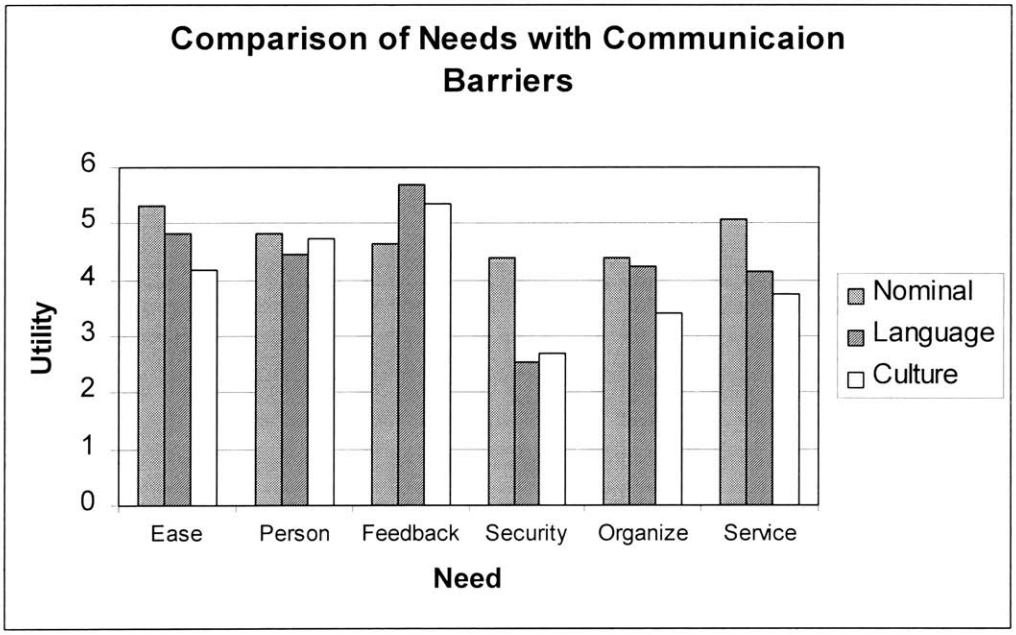

Figure 4.17: Modified Communication Needs in the Presence of Barriers

Using the revised utility of needs in the presence of cultural barriers, the overall utility of media can be recomputed using the modified relative needs preferences for both culture and language. To perform this calculation, we develop a modified average utility for each need based upon the ratio of the weight of the need relative to other needs. For the nominal case using the Sponsor Company sample survey results without consideration for cultural or language barriers, we use the mean ratings for the utility of media as defined in Section 4.1.3. For example, for E-Mail, we have the mean utility ratings for how well E-Mail satisfies each

of the needs under consideration in the survey. These mean utilities are represented as follows:

$\bar{x}_{Email,Ease}$ = Mean of ratings for E-Mail Ease-of-Use

$\bar{x}_{Email,Person}$ = Mean of ratings for E-Mail Ability-to-Personalize

$\bar{x}_{Email,Feedback}$ = Mean of ratings for E-Mail Feedback

$\bar{x}_{Email,Security}$ = Mean of ratings for E-Mail Security

$\bar{x}_{Email,Organize}$ = Mean of ratings for E-Mail Ability-to-Organize

$\bar{x}_{Email,Service}$ = Mean of ratings for E-Mail Reliability-and-Service

The weights associated with each need used in computing the utilities for media as given in Table 4.7 are computed using the average raw data weights associated with each mode of communication. For example, from Section 4.1.3, we have that the weight associated with the Ease-of-Use for the Tacit-to-Explicit mode of communication is given by

$$w_{T2E,Ease} = \frac{\bar{y}_{T2E,Ease}}{\bar{y}_{T2E,Ease} + \bar{y}_{T2E,Person} + \bar{y}_{T2E,Feedback} + \bar{y}_{T2E,Security} + \bar{y}_{T2E,Organize} + \bar{y}_{T2E,Service}}$$

where, $\bar{y}_{T2E,Ease}$ is the mean value of the responses for the survey question relating to the Ease-of-Use in the Tacit-to-Explicit mode of communication. The other values in the denominator of the equation above also represent corresponding mean responses from questions related to the utility of other needs associated with the Tacit-to-Explicit mode. In computing the values in Table 4.7, we have that the average responses across all modes of communication for any given need can be expressed as,

$$\bar{y}_{Ease} = \frac{\bar{y}_{T2E,Ease} + \bar{y}_{T2T,Ease} + \bar{y}_{E2T,Ease} + \bar{y}_{E2E,Ease}}{4}$$

Substituting values for the mean survey responses (raw data) contained in Figure 4.7, we have that the mean utility for Ease-of-Use overall is,

$$\bar{y}_{Ease} = \frac{4.844 + 4.969 + 4.969 + 5.000}{4} = 4.945$$

Using the overall mean responses for the needs across different modes of communication, the overall weight factor for each need is calculated in a fashion similar to the weight factors for the communication mode specific case as outlined above. Thus, the weigh factor for Ease-of-Use (averaged over all four communication modes) is given by,

$$w_{Ease} = \frac{\bar{y}_{Ease}}{\bar{y}_{Ease} + \bar{y}_{Person} + \bar{y}_{Feedback} + \bar{y}_{Security} + \bar{y}_{Organize} + \bar{y}_{Service}}$$

Substituting values,

$$w_{Ease} = \frac{4.945}{4.945 + 3.234 + 4.328 + 2.516 + 3.844 + 3.891} = 0.217$$

The weight factors for individual needs in the presence of communication barriers studied are shown in Tables 4.15 and 4.16. Since the communication barrier questions did not consider different modes of communication, the procedure for calculating weighting factors in the presence of culture and language barriers are similar to the procedure used for the raw data sample given the overall utility for each communication need as averaged across the four

modes of communication (T2E, T2T, etc.). To illustrate the calculation of these weighting factors, we consider the weight factor applied to Ease-of-Use in the presence of culture barriers. Similar to the overall weight calculation described above for Ease-of-Use, we have that,

$$w^c_{Ease} = \frac{\bar{y}^c_{Ease}}{\bar{y}^c_{Ease} + \bar{y}^c_{Person} + \bar{y}^c_{Feedback} + \bar{y}^c_{Security} + \bar{y}^c_{Organize} + \bar{y}^c_{Service}}$$

where each term $\bar{y}^c$ represent the mean responses from the survey to the relative importance of the needs when cultural barriers were presents. Substituting the mean responses to the relative utilities of communication needs in the presence of cultural barriers from Table 4.16,

$$w^c_{Ease} = \frac{4.182}{4.812 + 4.727 + 5.364 + 2.682 + 3.409 + 3.727} = 0.174$$

The other cultural barrier weight factors for the needs are calculated using a similar weighting procedure.

Given the weight factors for the nominal case and the case when cultural barriers are present, the communication needs from the nominal case can be weighted to produce individual utilities for media for each mode of communication. For example, the utility of E-Mail calculated for the Tacit-to-Explicit mode of communication can be scaled to adjust for the new weights derived for the situation where cultural effects are presents. Such scaling is performed using the ratio of weight factors between the nominal and culture barrier case as follows:

$$U^{c}_{Email,T2E} = \frac{w^{c}_{Ease}}{w_{Ease}} w_{T2E,Ease} \bar{x}_{Email,Ease} + \frac{w^{c}_{Person}}{w_{Person}} w_{T2E,Person} \bar{x}_{Email,Person}$$
$$\frac{w^{c}_{Feedback}}{w_{Feedback}} w_{T2E,Feeedback} \bar{x}_{Email,Feedback} + \frac{w^{c}_{Security}}{w_{Security}} w_{T2E,Security} \bar{x}_{Email,Security}$$
$$\frac{w^{c}_{Orgamize}}{w_{Organize}} w_{T2E,Organize} \bar{x}_{Email,Organize} + \frac{w^{c}_{Service}}{w_{Service}} w_{T2E,Service} \bar{x}_{Email,Service}$$

The above equation is an expanded form of the original equation, presented in Section 4.1.3 for the utilities of context-specific media. i.e.,

$$U_{Email,T2E} = \sum_{j=1}^{6} w_j \bar{x}_{Email,j}$$

As with the utilities calculated for media using the raw data from the Sponsor Company survey sample responses without consideration of cultural and language effects, overall media utilities are calculated for the culture by averaging across different modes of communication,

$$U^{c}_{Email} = \frac{U^{c}{}_{Email,T2E} + U^{c}{}_{Email,T2T} + U^{c}{}_{Email,E2T} + U^{c}{}_{Email,E2E}}{4}$$

Using the above approach to account for cultural and language effects upon the utilities of media, the results were calculated for all media and all modes based upon both the effect of language and culture. Detailed results for the effect upon language are presented in Table 4.17 and 4.18. Table 4.17 contains the basic utilities for media against the needs. Table 4.18 presents the language effect breakdown of needs for the individual modes of communication studied. Similar results for cultural effects are presented in Tables 4.19 showing media

utilities and Table 4.20 that contains the breakdown of the utilities for different communication modes.

Table 4.17: Sponsor Company Media Utilities with Language Barrier Present

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean	Utility	Percent Utility
E-Mail	5.092	4.271	5.529	2.058	4.780	4.104	4.539	75.7%
Video	2.716	3.533	4.813	2.009	2.767	2.340	3.196	53.3%
F2F	4.828	5.502	7.014	3.220	3.897	4.307	5.031	83.8%
Voice	4.715	4.657	5.888	2.494	3.656	4.104	4.473	74.6%
Web	3.621	2.644	3.628	1.642	3.944	3.291	3.260	54.3%
Fax	4.187	3.252	3.942	1.525	3.856	3.459	3.540	59.0%
Pager	3.750	2.867	3.277	2.324	2.464	3.213	3.058	51.0%

Table 4.18: Sponsor Company Ratings of Needs for Communication Modes with Language Barrier

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean
T2E	4.736	5.202	5.838	2.512	3.884	4.007
T2T	4.942	4.507	5.675	2.385	4.067	3.897
E2T	4.653	4.437	6.185	2.871	3.884	4.055
E2E	4.942	3.672	5.029	2.414	5.075	4.586
Needs Avg.	4.818	4.455	5.682	2.545	4.227	4.136
Weighted Avg.	0.186	0.172	0.220	0.098	0.163	0.160

Table 4.19: Sponsor Company Media Utilities with Cultural Barrier Present

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean	Utility	Percent Utility
E-Mail	4.420	4.532	5.220	2.168	3.855	3.698	4.178	69.6%
Video	2.357	3.749	4.543	2.117	2.231	2.109	3.034	50.6%
F2F	4.190	5.839	6.621	3.393	3.142	3.881	4.770	79.5%
Voice	4.092	4.942	5.558	2.627	2.948	3.698	4.199	70.0%
Web	3.143	2.806	3.425	1.730	3.181	2.966	2.960	49.3%
Fax	3.634	3.451	3.722	1.607	3.110	3.117	3.238	54.0%
Pager	3.255	3.043	3.093	2.449	1.987	2.895	2.853	47.5%

Table 4.20: Sponsor Company Ratings of Needs for Communication Modes with Cultural Barrier

	Ease Mean	Person Mean	Feedback Mean	Security Mean	Organize Mean	Service Mean
T2E	4.110	5.521	5.511	2.647	3.132	3.611
T2T	4.289	4.783	5.357	2.512	3.280	3.512
E2T	4.039	4.709	5.839	3.025	3.132	3.654
E2E	4.289	3.897	4.747	2.544	4.092	4.133
Needs Avg.	4.182	4.727	5.364	2.682	3.409	3.727
Weighted Avg.	0.174	0.196	0.223	0.111	0.142	0.155

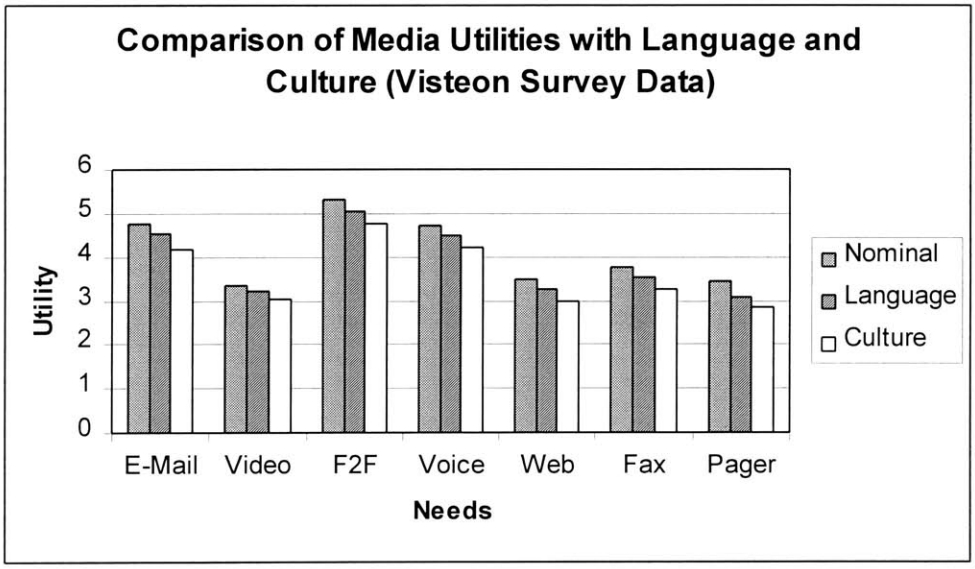

Figure 4.18: Media Utility Variation in the Presence of Communication Barriers

Figure 4.18 shows the utility preferences as calculated based upon the needs from the nominal Sponsor Company survey as compared to the utilities for the same media when adjusted for the effects of language and culture. Since language differences are generally associated with the presence of cultural barriers, one can interpret language as being a subset of overall cultural effects upon the communication process. This is confirmed by the trend observed in the change in media utilities once language and subsequently cultural effects are

considered. For each medium, language barriers resulted in a decline in the overall utility. Furthermore, when cultural effects were considered, resulting media utilities declined even further for each medium. Nevertheless, the overall trend in media utilities was preserved, where Face-to-Face ranked highest, followed by Voice and E-Mail.

The net effect of language (a subset of cultural effects) is to reduce the utility of all media, and the introduction of the full effect of all cultural barriers to communication results in even further decline in media utilities. The fact that the media utilities relative to each other did not change is somewhat surprising, given the relative change in the importance of different communication needs when cultural and language effects were introduced (as shown in Figure 4.17). The most significant observation from Figure 4.17 is that the need for Feedback increased with culture and language differences. However, individual media were not as sensitive to the resulting changes in preferences for communication needs due to language and culture barriers, since the best performing media actually scored highest in Feedback, as can be seen in Figure 4.16.

4.3.5 Variations in Culture and Language Differences (Sponsor Company Data)

In the survey administered to Sponsor Company respondents, questions were asked to assess and quantify the perceived level of cultural and language differences that exist between each respondent's location and other global locations with which the respondent was required to interact in order to perform their role on a globally dispersed team. Both cultural and language effects were ranked on a scale of 1=No Difference to 6=Significant Difference. Mean rankings for the level of language differences as indicated by the survey respondents

between their geographic location and other countries and geographic areas are shown in Table 4.21.

It should be noted that, while many geographic regions were considered in the survey, not all geographic regions were represented by the demographics of the survey respondents. Since many of the respondents interacted with other regions that were not represented themselves by the mix of respondents, there are more regions represented by the list of regions in the column labeled "To" as opposed to the regions identified as "From". As a result, a reduced data set was derived from Table 4.21 that contains only ratings where ratings were available in both directions of information flow; in this reduced set of data ratings for both "To" and "From" information flow language effects are known. Therefore, Table 4.22 was constructed from a reduced subset of the survey responses so that it contains data for which respondents were represented in both the "To" and "From" regions.

Table 4.22 also was modified from the original data to account for the fact that intra-country communications should have the lowest language barrier, i.e., a ranking of 1.0. For example, the data in Table 4.21 shows that the level of cultural differences in the "From"-"To" pair for France shows the highest ranking of 6.0 for language effect. In fact, a respondent located in France whose native language (English) was other than French assigned this cultural effect. However, English is considered within the Sponsor Company as the official language for conducting business. Since some other respondents were also expatriates assigned to foreign countries, there are confounding effects present in the data that cannot be entirely resolved to account for accurate description of the perceptions of local nationals. Many global teams within the Sponsor Company contain expatriates working and representing the interests of

foreign operations. Therefore, it may not be possible to entirely resolve the confounding effect of expatriates upon perceived language and cultural differences between geographic regions. Nevertheless, all intra-country language and cultural ratings are assumed to be 1=No Difference for purposes of subsequent analysis.

From Table 4.21 it is evident that the perceived language effects are not symmetric. For example, in sending messages from Japan to Germany, the mean ranking of language effects was 3.7, while going from Germany to Japan, the effect was observed to be higher at 4.7. This is significant in that not all communication is perceived equally when two individuals are communicating. Language and culture can introduce asymmetries in the perceived level of satisfaction of communication needs and overall communication effectiveness.

Cultural effects are summarized in Table 4.23. A similar reduced format subset was developed using the data and adjustments and for intra-country cultural differences that were set to 1=No Difference as contained in Figure 4.24. Since both Table 4.22 and 4.24 contain a complete set of responses for both "To" and "From" language and cultural barriers, only these results will be employed in subsequent analysis to develop ratings for the effectiveness of media in communication between different geographic regions.

Table 4.21: Summary of Language Effect Mean Responses by Region (Sponsor Company Data)

		From				
		Japan	France	Germany	U. K.	N. America
To	Australia	2.3		2.0	2.0	1.3
	Japan	3.3	5.0	4.7	2.3	2.9
	India	3.0		3.5	1.5	2.3
	Other Asia	4.3		5.0	3.0	3.7
	Brazil	3.5		3.5	3.0	2.8
	Mexico	3.5		3.0	3.0	2.8
	France	3.5	6.0	3.0	3.5	3.3
	Germany	3.7	4.0	3.0	2.0	2.5
	U. K.	2.3	1.0	1.3	1.3	1.6
	Other Europe	4.0		2.3	2.7	3.0
	N. America	2.0	5.0	1.0	1.5	1.2
	Africa	3.5		4.0		1.0

Table 4.22: DSM Subset of Language Effect Data by Region (Sponsor Company Data)

		To				
		Japan	**France**	**Germany**	**U. K.**	**N. America**
From	**Japan**	1.0	3.5	3.7	2.3	2.0
	France	5.0	1.0	4.0	5.0	5.0
	Germany	4.7	3.0	1.0	1.3	1.0
	U. K.	2.3	3.5	2.0	1.0	1.5
	N. America	2.9	3.3	2.5	1.6	1.0

Table 4.23: Summary of Culture Effect Mean Responses by Region (Sponsor Company Data)

		From				
		Japan	France	Germany	U. K.	N. America
To	Australia	2.0			2.0	1.7
	Japan	2.5	5.0	5.5	5.0	4.8
	India	3.0		4.0	4.0	5.7
	Other Asia	3.7			5.0	5.3
	Brazil	3.0		3.0	3.0	4.2
	Mexico	3.0			3.0	3.7
	France	3.5	1.0	3.3	3.0	2.5
	Germany	3.8	4.0	3.0	3.3	3.3
	U. K.	3.0	4.0	3.0	1.3	2.6
	Other Europe	3.0	4.0	3.3	3.3	3.2
	N. America	2.5	5.0	1.5	2.3	1.4
	Africa	3.0				6.0

Table 4.24: DSM Subset of Culture Effect Data by Region (Sponsor Company Data)

		To				
		Japan	**France**	**Germany**	**U. K.**	**N. America**
From	**Japan**	1.0	3.5	3.8	3.0	2.5
	France	5.0	1.0	4.0	4.0	5.0
	Germany	5.5	3.3	1.0	3.0	1.5
	U. K.	5.0	3.0	3.3	1.0	2.3
	N. America	4.8	2.5	3.3	2.6	1.0

4.3.6 Summary of Results from Sample (Sponsor Company) Survey Data Analysis

Results from the Sponsor Company sample population survey generally confirmed the results of the factor analysis performed on the control population survey results although some differences in the correlated needs factors were observed. Differences in the correlated factors were attributed to several characteristics of the Sponsor Company environment that combined to produce factors that represented trade-offs (i.e., negatively correlations) among the needs. One such characteristic was the presence of a greater degree of trust present in the Sponsor Company communication environment due to the fact that all survey respondents belonged to the same corporate enterprise. Other characteristics thought to have influenced the survey results correlations include the presence of a secure internal communications network and consideration of and increased sensitivity for preservation of the integrity of proprietary company information. Nevertheless, factor analysis and perceptual mapping confirmed that the communication needs preferences within the Sponsor Company population were consistent with the control survey derived factors of:

- User Friendliness.
- Privacy
- Feedback

In fact, with the Sponsor Company survey, Feedback was a uniquely correlated factored need.

Associated with the factor analysis of Sponsor Company data were three distinct clusters of respondents. These groups are characterized by the following phrases, as shown in the Figure 4.10. Another cluster consisting of only two respondents was equally balanced in preferences for the User Friendliness and Privacy dimensions, except that this group exhibited a reduced preference for the need for Feedback.

As with the control survey results, the utility preference for individual communication needs is mostly independent of the mode of communication, with the exception of the Explicit-to-Explicit mode. This mode was consistent with a reduced need for Feedback and Personalization and an increased need for the Ability-to-Organize information.

The most effective comparisons for media are based upon the utilities resulting from the Sponsor Company data sample are also consistent with the control survey population, where Face-to-Face, Voice and E-Mail ranked highest on all three dimensions of User Friendliness, Privacy and Feedback. However, as was discussed in Section 4.2.9 with regard to the research performed by of Allen (1977) and Sosa (2000), the fact that the utilization of particular media is confounded in global teams due to dispersion in space and time.

In considering the effects of the presence of culture and language differences, the Sponsor Company survey showed that media utilities decline with the introduction of culture and language barriers as shown in Figure 4.18. Furthermore, the introduction of such barriers is associated with significant changes in preferences for communication needs. Figure 4.17 illustrates that the need for Feedback increases significantly with the introduction of cultural and language barriers while the need for Security drops dramatically. The relative strength of language and cultural barriers was also studied. Tables 4.22 and 4.24 include relative

cultural barriers that will be used in subsequent DSM analysis to weight the appropriate communication needs for individual pairs communication between specific geographic regions. Results of this analysis are discussed in Chapter 5.

5.0 Design Structure Matrix (DSM)

The Design Structure Matrix (DSM) methodology is one alternative technique for the analysis and management of product development projects (Eppinger et al., 1994). The DSM is particularly useful in that it offers a much more compact representation of the tasks and activities of a development process than widely used project management tools such as PERT or CPM (Wiest and Levy, 1977).

The DSM is essentially an *n*-by-*n* matrix representing *n* individual tasks associated with a particular process. The DSM is typically populated by *m* non-zero entries, which are represented by a "1" or "X". Each "X" in a matrix indicates a dependency between two tasks that correspond to an arrow in a directed graph (i.e. digraph) representation of the process typically used with "activity-on-node" (AON) process models such as PERT. For example, if the DSM matrix has a non-zero entry in the *i-th row* and *j-th* column, this indicates that the *i-th* task has outputs that are inputs to the *j-th* task in the process. The benefit of such a representation is that the representation of forward and feedback loops can be simultaneously included in the matrix structure. A typical PERT diagram, when mapped into a DSM would have non-zero entries only in the lower diagonal part of the matrix, whereas the DSM with entries on both sides of the diagonal is indicative of a process that also includes feedback mechanisms.

DSM has proven versatile in its breadth of analysis. Early applications of DSM were focused on modeling processes that involved many iterative loops. Once the DSM was generated for a given process, dependent tasks could be regrouped using sorting and partitioning algorithms that rearranged the tasks in a sequence that minimized the number of feedback

loops (Yassine et al., 1999). Sorting methods applied to DSM result in a restructured sequence of tasks that represent a more efficient process wherein information flow is optimized. As a result, all tasks are ideally rearranged such that information required for any given task is available by virtue of the fact that all other tasks from which information is required for the given task are completed first.

In general, the sorting process in general cannot entirely eliminate feedback loops in the process, but does result in the identification of more compact cyclic loops within the overall process. Such cyclic loops appear in the sorted DSM as blocks along the main diagonal that consist of interdependent tasks that are tightly linked by iterative information flows between them. The sorted DSM also clearly identifies tasks that must be performed in series, where a particular task requires inputs from preceding tasks, and tasks that can be performed in parallel, where no informational dependencies exist.

Even without analysis, a DSM can provide a wealth of information as a visual model of a development process. A visual inspection of the modeled process can provide insights into process, product and organizational architecture.

Table 5.1 details the traditional DSM approach to product development modeling and management.

Table 5.1 Traditional Analysis of the Design Structure Matrix

	Process	Goal	Value
1	Build the DSM	Build a matrix representation of the design process	Identify/organize task sequences and relationships in a compact form
2	Sort the DSM	Achieve a sequence for the tasks with no feedback information flows	Provide smoother information flow where all requisite information for a task is available before it
3	Cycle detection	Identify the existence of cyclic information flows	Recognize the existence of iteration in the design process
4	Partitioning of the DSM	Group tasks (involved in an information loop) in a block around diagonal of matrix	Identify iteration task subsets to focus on instead of all tasks in the DSM

Yassine et al, 2000

The DSM methodology has also been extended from process modeling to other organizational problems, such as system design architecture. In system architecture applications, the project tasks are replaced with functions and functional relationships that exist within a physical system. Functions can be represented by components, or, as is more commonly used, design parameters associated with components and overall system performance attributes. For example, one functional element of an automotive chassis is the steering subsystem. The steering subsystem interacts with the suspension and tires to produce directional control of the automobile. However, steering characteristics (ride and handling) are not defined by a sequential, cause and effect relationship from the steering gear, through the suspension to the tires, but are the result of the interplay and interaction of design parameters of all components that must be synchronously calibrated to achieve the

desired performance effect (attribute). Therefore, DSM can be a very powerful methodology when applied to the design itself and not just the process.

Perhaps the most intriguing of all applications for DSM is the ability to not only model processes and the design architecture, but also the organizational structure required to deliver the product of process. Team based DSM models are based on the premise that information flow within teams involves an iterative exchange that must agree with the overall process or product architecture, wherein individual team members or functional organizations must interact to achieve communication required to exchange information required between tasks or design functions. One application for team DSM is in defining cross-functional team membership based upon the sorted DSM from a process model. Essentially, once a sub-block of tasks has been identified as the result of a sorting of a DSM, a corresponding team can be identified based upon the organizational distribution of responsibilities for the interrelated tasks. Once the team composition required for a given set of tasks that are highly coupled has been identified, appropriate attention must be paid to collocation (grouping) or other methods (linking and alignment) that promote constructive organizational interfaces to ensure appropriate intensity of communication are required.

While DSM is useful in identifying the need for grouping, linking and alignment mechanisms required for effective organizational interfaces, such studies do not themselves provide any measure of the effectiveness of proposed remedies. However, recent organizational DSM models (Eppinger et al 1997) have successfully demonstrated application to understanding the significance of organizational interfaces vis-à-vis the required information flows as identified by product architecture. In this approach, a DSM was constructed representing

product architecture and a corresponding DSM representing the organization assembled to deliver the product. The existence of forward and feedback dependencies in the product architecture should correspond to information flows across appropriate organizational interfaces. However, this study was able to demonstrate that communication sometimes did not occur across organizational boundaries when product architecture indicated a need for collaboration, and did occur in other circumstances when product architecture did not necessarily indicate an informational dependence. In this example, DSM proved an effective tool for assessing the relative degree of linking present within the team.

The ability to predict communication among teams has been further developed using DSM. The methodology has been extended to the analysis of communication and the effect of choice of media (Sosa, 2000). The numerical DSM contained a multiple variable vector of attributes that captured the effects of distance and frequency upon the choice of communication media. This example further demonstrates the ability of DSM to capture and analyze the effects of linking and alignment mechanisms when teams are globally dispersed. By extending the study to the analysis of the effect of media, the work of Sosa et al (2000) introduces an important aspect of linking across organizational boundaries with regard to the context of how information is conveyed.

Numerical Design Structure Matrix (NDSM)

The numerical DSM (NDSM) is derived from the traditional DSM by replacing the "X" with a numerical value that represents the strength of the informational dependency between tasks. The values used in populating a NDSM can be based on the probability that a given task will have to be repeated if the information from a given feedback information loop is inaccurate

or nonexistent. The numerical ranking of the relative strength of feedback effects can be employed in the process of "tearing" the DSM. Tearing is a process that attempts to unravel the tight-knit feedback loops within DSM blocks by developing a new sequence of tasks for the sub-block that reduces the likelihood of multiple iterations. Tearing is essentially an attempt to break the cycles of information flow within a block by allowing some tasks (within the block) to proceed without complete predecessor information through required, but unavailable development information.

Numerical DSM has been extended from using a single analysis variable to include a vector of parameters that can be simultaneously analyzed. As an example, the analysis of sensitivity and variability effects of dependencies between tasks was conducted by Yassine et al. (1999). Sensitivity is defined as a measure of how sensitive a given task is to information changes from a predecessor task. Variability is a further measure of the likelihood that the output of a task can be predicted given the start of the subsequent task. In this example, the combined effect of both feedback mechanism parameters was estimated by multiplication of the two factors. The product of both sensitivity and variability resulted in a single measure to be applied to the NDSM to assess the effect upon the overall product development process.

Work Transformation Matrix (WTM)

The Work Transformation Matrix (WTM) is a numerical DSM with a non-zero main diagonal, whose values represent the mean duration of each task. The off-diagonal entries reflect the probabilities that a unit quantity of work performed on a given task will create additional work (i.e. rework) in other dependent tasks. Such rework often arises when attempting to complete a task based on inaccurate or incomplete information.

The Work Transformation Matrix (WTM) models design iteration by analyzing a set of previously sorted and partitioned tasks with the objective of characterizing the nature of design iterations. This analysis involves controlling features and total work analysis based on the following assumptions (Smith and Eppinger, 1997a):

- Every task is performed during each iteration stage - fully parallel iteration.
- Each task creates a deterministic amount of rework for other tasks.
- Rework performed in current iteration stage is a function of work performed in the previous iteration stage.
- The rework transformation parameters do not vary with time.

Total work analysis involves the construction of a matrix "*A*", where each cell value depicts the strength of the dependencies between the interacting tasks. If "*A*" is a square matrix with linearly independent eigenvectors, the eigenvectors and eigenvalues can be used to identify a closely related groups of tasks referred to as design modes. Tasks belonging to a design mode are so closely related that performing work on any one of them results in the creation of a significant amount of work directly or indirectly for the other tasks.

The eigenvectors and eigenvalues of the matrix characterize the convergence of the process. The relative contribution of each task to the total process is depicted by the eigenvector corresponding to the eigenvalue associated with that particular task. The largest value in the eigenvector corresponds to the task that contributes most to the design mode, whereas the

magnitude of the eigenvalue of a task characterizes the geometric rate of convergence of the design mode in which it belongs. The larger the eigenvalue, the lower the rate of convergence and thus the slower the design mode.

Ranking design modes and tasks that contribute to these modes identifies the controlling features of iterations. Also ranking eigenvalues and entries in eigenvectors determines the rank of design modes and task contributions.

Applying the WTM to the communication process enables us to identify structures that facilitate convergence, which in this case is the state where all team members have received, interpreted and understood correctly all useful information. WTM applied to communication replaces the notion of total work done with total information processed. The method can be applied in essentially the same fashion to communication as to the work matrix except that the results depict the convergence of information flow and processing. Convergence of information flow is analogous to a consensus based decision process, where all team members receive adequate information to contribute to a team decision. It is important to keep in mind that decisions, just as work in the work transformation matrix, are sometimes necessary even in the absence of perfect information.

5.2 Determining WTM Probabilities Using Media Utility

The utilities associated with media as derived in Chapter 4 provide a quantitative measure of the degree to which media satisfy the needs for communication. These utilities can be applied to the analysis of communication dynamics within a team. This is based on the fact that communication occurs with the primary intent of conveying information content for the

purposes of transferring knowledge. We can make the assumption that, as the utility of media decreases, the effectiveness of transfer of such information and knowledge declines. Using the utility of media as a basis for defining the efficiency of communication implies the following relationship to efficiency with respect to the needs identified in the factor analysis of Chapter 4:

- The sender is able to accurately and precisely articulate the desired knowledge and information to be conveyed in the message in a well-organized arrangement (User Friendliness).

- The sender has the ability to transmit the message with assurances that it will be delivered to the appropriate recipient without being compromised (Privacy).

- The receiver is able to comprehend and understand the message as intended by the receiver and is unconstrained by the medium in his ability to respond and convey further information or effect any decisions based on the information received in the message (Feedback).

Using the scale for utilities ranging from one to six as developed in Chapter 4, we can assume that, if a particular medium has a utility rating of six (the highest possible utility), this would be 100% efficient medium in transmitting information (tacit or explicit). Correspondingly, a medium with a utility rating of one is assumed to have an efficiency of zero with regard to its ability to support the transfer of information and knowledge. Using this definition, the utility of media becomes a quantitative assessment of how media contribute to the overall efficiency of the processes of communication.

The relationship between media utilities and overall efficiency of the communication process can also be illustrated by understanding how the communication needs factors (User Friendliness, etc.) correspond to the processes that can be derived from the functional decomposition of communication. Functional decomposition is a system engineering methodology for deriving lower level needs or processes from a fundamental need such as communication. Figure 5.1 depicts a functional decomposition of the need for communication in the context of using a shared database. The first level decomposition of needs in Figure 5.1 represents general purpose functional needs (Send, Receive, Interpret) that apply to any communication process. It is only at the subsequent levels of decomposition that the specific requirements of the medium are introduced.

Considering the example in Figure 5.1, communication via a database is typically asynchronous, in that the process of sending information to the database and retrieval of information are separated in time. Nevertheless, the need to be able to Send, Receive and Interpret information is essential for any communication medium irrespective of synchronicity. For the database example, the first level decomposition includes Send functions, such as requesting access to and updating information. Such functions are closely associated with the User Friendliness of the medium. Receive functions include actual retrieval of information from the database. Such functions are dominated by needs for both User Friendliness and Privacy needs. Interpret functions, such as processing update requests and formatting reports, is closely aligned with the need to support the ease of Feedback of the medium along with User Friendliness. This example clearly illustrates the correspondence of the needs and associated utility of the medium with its ability to support the processes associated with communication.

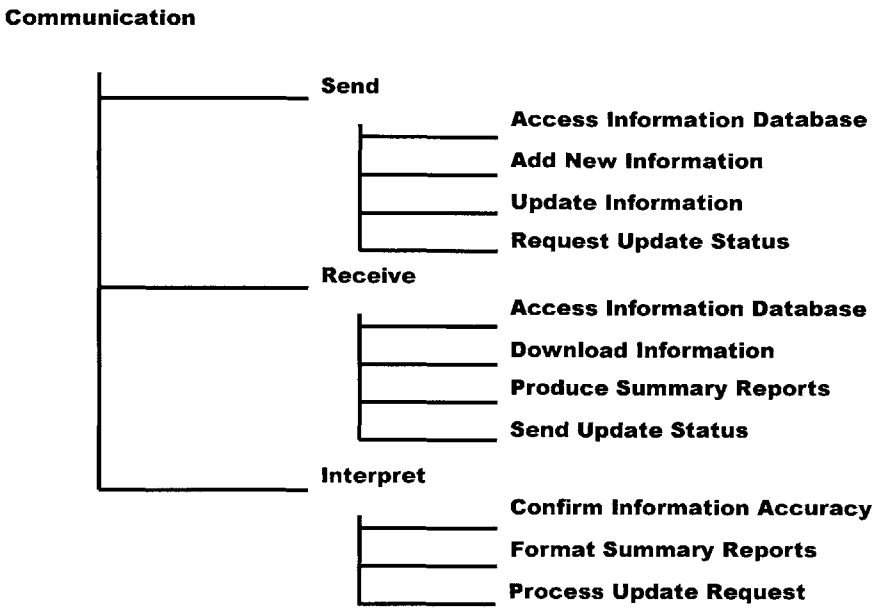

Figure 5.1: Decomposition of Database Communication Process

Figure 5.2 depicts an alternate version of the first level decomposition of the communication process (Greenberg and Baron, 1995). The major distinction with this functional decomposition is the separation of the Interpret function into two individual processes of encoding and decoding of information associated with the Send and Receive functions. This model also includes Feedback as an explicit function. As with the functional decomposition discussed in Figure 5.1, media specific functional needs are introduced one level below the decomposition shown. For the database example discussed above, the process of Encoding involves data formatting into a specific syntax for entry into a formatted database. Other media, such as voice, can involve entirely different encoding processes. Nevertheless, the first level functional decomposition is applicable to all communication processes and the basic needs of User Friendliness, Privacy and Feedback attributed to media as defined in Chapter 4 directly influence the effectiveness of the communication process. Therefore, the

use of utilities of media as an indication of the efficiency of the communication process remains valid.

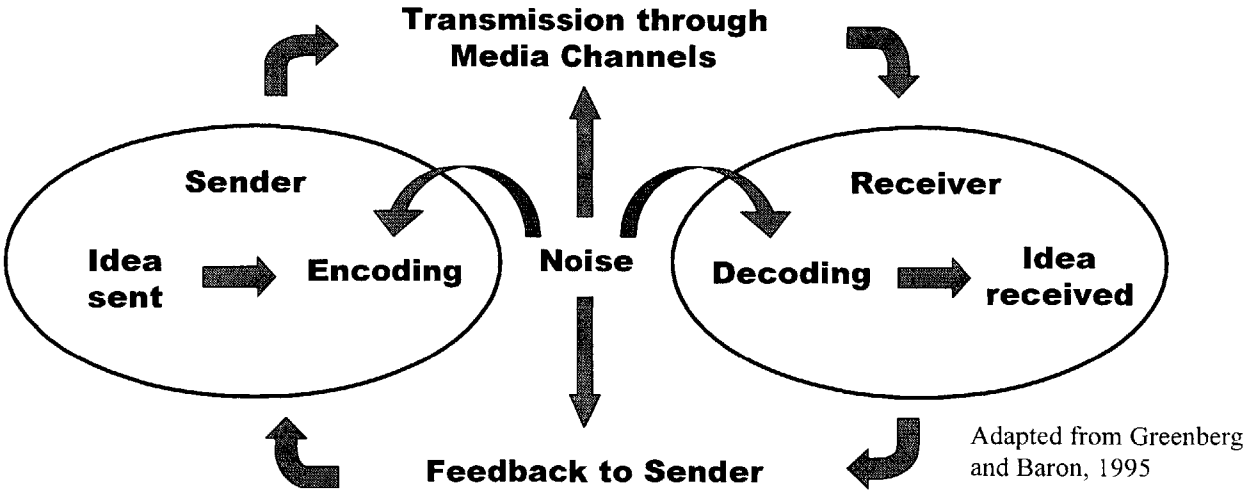

Figure 5.2: Communication Model Illustrating Functional Decomposition

The Greenberg and Baron communication model also recognizes the fact that the communication process rarely operates flawlessly by introducing the concept of Noise. Such noise acts to reduce the effectiveness of the communication process. Noise can arise from difficulties directly associated to the use of media (transmission losses, reliability of service, lack of security, etc.) as well as other factors, such as the influence of communication barriers such as distance, language and cultural barriers. Thus, noise accounts for degradation in the communication process due to both inferiority of utility of media as well as the presence of other barriers.

With the concept of attributing noise to both the influence of media and barriers to communication, we can estimate the efficiency of communication using the utilities of media

calculated in Chapter 4 for individual media in the presence of language and cultural barriers. We can define efficiency (ε) as the ratio of information that is received as compared to the total quantity of information that was sent.

$$\varepsilon = \frac{Quantity\ of\ Information\ Received}{Quantity\ of\ Information\ Sent}$$

While it is difficult to measure "quantities of information" the notion of a unit of information or knowledge transmitted can be introduced. For purposes of this study, a unit of knowledge or information is arbitrarily defined as equivalent to a statement of fact or metaphorical concept (explicit) or a statement of opinion or sensation (tacit).

The exact content or nature of the information conveyed is not considered, only that an instance of a communication process involves the transmittal of one such "unit" of information. Thus, efficiency is defined as the ratio of information received and understood (decoded) to the original quantity of information encoded and sent. Alternatively we can describe this as the probability that a unit of information, once sent, does not arrive and is not properly decoded by the sender, i.e., p_{ij} is the probability that a unit of information sent by the i-th person is somehow not received (lost) or inaccurately decoded by the j-th individual on a team. The probability that information is lost is directly related to the media efficiency,

$$p_{ij} = 1 - \varepsilon$$

Using the utilities of media, we can approximate the probability that information is lost as a result of the communication process. First, we introduce the following limits to the

probabilities associated with the maximum value of six and minimum value of one for utilities as derived in Chapter 4 of any given medium. Thus,

$p_{ij} = 1$ if the utility of medium is equal to one, or $U_{ij} = 1$

$p_{ij} = 0$ if the utility of medium is equal to six, or $U_{ij} = 6$

For media utilities that range in between the limits of the scale of one-to-six, an interpolation must be employed to associate probabilities that information is lost to the value of media utilities. One such interpolation is using a linear approximation, wherein the probability that information is lost is directly proportional to the utility of the medium. Hence,

$$p_{ij} = 1 - \frac{U_{ij} - 1}{6 - 1} = 1 - \frac{1}{5}\left(U_{ij} - 1\right)$$

where U_{ij} is the utility associated with the medium for communication between the i-th and j-th individuals.

Such probabilities are useful although they cannot be applied directly to the DSM based Work Transformation Matrix (WMT). The WTM is applied to a task-based DSM and utilizes probabilities associated with specific tasks to indicate the likelihood that performing a unit of work in a given task will result in additional downstream work (i.e., repeating the task). The probabilities calculated from the efficiencies of media contribute to the generation of further communication downstream as a result of the lack of sufficient information being transmitted initially. Nevertheless, the probabilities that additional information flow is

generated is a function of the learning that takes place and the extent to which the team is willing to make decisions, thereby precluding the need for additional information, given that information to make a decision is incomplete.

The probability that information is lost in the communication process is related to the probability that future iterations of the communication process will result in information being retransmitted. Such iterations of information flow will continue until the process converges. A converged process is one where enough useful information has been conveyed and understood by all members of the team in order to reach a consensus to make a decision. Therefore, we must introduce a new probability quantity associated with the WTM matrix A_{ij} that indicates the likelihood that information introduced into the network by the i-th team member will result in additional information processing by the j-th individual,

> A_{ij} = Work Transformation Matrix probability that a unit of information produced by the i-th member of the team will result in additional information being generated by the j-th person on the team.

The usefulness of information in the context of the DSM is indicated by the information dependencies captured in a communication-based DSM. Such communication dependencies between individuals are defined to exist only when there is a non-zero entry in the cell of a DSM corresponding to the interaction between two team members. In order to apply the WTM analysis, we must therefore relate the WTM probability A_{ij} to the utility of media U_{ij} as computed in Chapter 4. We can develop this relationship using the dynamics of the learning

process (Section 5.2.2), concurrence relationships (Section 5.2.3) and that the fact that utilities are related to the communication efficiency based probability $p_{ij} = 1 - \varepsilon$.

Convergence of the communication process is constrained by the requirement that the sum of the probabilities in the WTM across any row is less than 1,

$$\sum_i A_{ij} < 1$$

This requirement is a consequence of the fact that, if the sum of probabilities were greater than one for a given individual, then the act of sending one unit of information to the team will result in more than one unit of information being resent in a subsequent iteration. However, subsequent information, when sent again, results in even more downstream communication. Such a communication process will continue to escalate and diverge if left unchecked. Further discussion of the dynamics of such divergent processes is presented in Section 5.4.

5.2.1 Learning Curve Processes

While the linear interpolation may be valid, a better approximation for the relationship between utilities and the probability that information will be lost can be developed by incorporating the dynamics of learning processes. If learning is considered to occur in the communication process, then any portion of a given message that successfully reaches the recipient will be available to the recipient during subsequent events. In the event of retransmission of the message during a subsequent iteration, the loss of any portion of the information that was already received during prior iterations will not require further

communication. This is due to the learning that has already taken place, whereby the recipient can reassemble the original message by combining any newly received information contained in the retransmitted message with old information learned from prior iterations of the communication process. Therefore, the mechanism of learning increases the probability of success in the communication process by reducing the likelihood of future iterations of the communication process.

Learning dynamics are a familiar type of goal-seeking behavior. Goal-seeking system dynamics have the characteristic behavior in that the system effects a corrective action that is proportional to the gap between the actual response of the system and desired goal for the response (Sterman, 2000). When the rate of adjustment is exactly proportional to the size of the gap, the resulting goal-seeking response mode is exponential decay. As the gap decreases, so does the adjustment. Such exponential decay models exhibit a characteristic half-life that is equivalent to the time required to reduce the gap by exactly one-half.

Figure 5.3 depicts a system dynamics causal loop diagram that illustrates the behavior of the goal seeking behavior of the communication model. The process begins with a certain desired quantity of information to be sent (I_s). The sender encodes the information and transmits the data through a medium at which point the recipient receives it. Since the process of encoding, transmitting and decoding information can involve losses due to the inability of media to satisfy all communication needs completely, only a portion of the information originally sent is received (I_r). As a result of the gap in information ($I_s - I_r$), the recipient sends a feedback request for more information to the sender. This process continues until a satisfactory level of information is transmitted to the recipient. This is a

classic example of a balancing system dynamic loop with the reference response mode exhibiting exponential goal-seeking decay as shown in Figure 5.4.

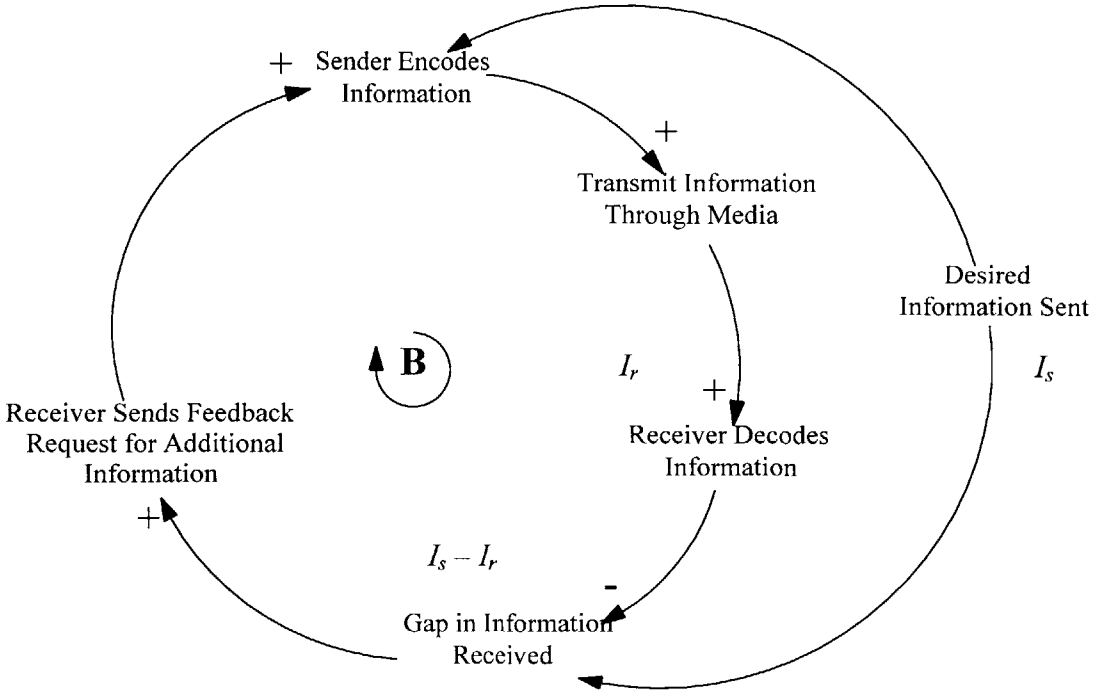

Figure 5.3: Causal Loop Diagram of Communication Process

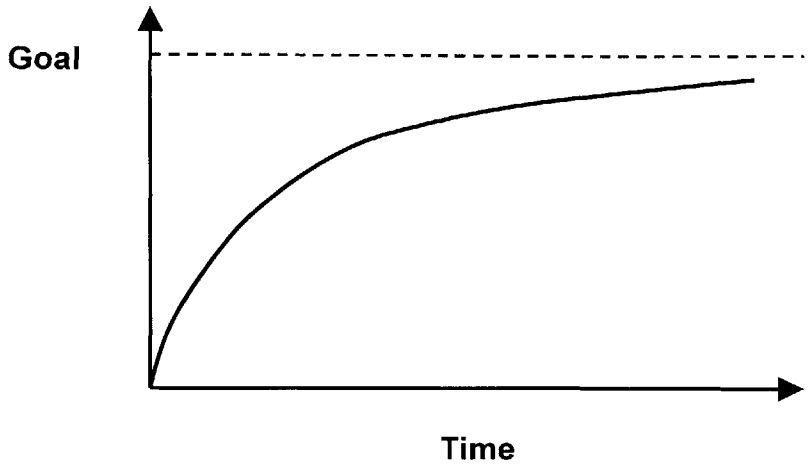

Figure 5.4: Response Mode for Goal Seeking Dynamic System

The response of the system can be characterized by the efficiency of the communication process. Since efficiency is the ratio of information received to the information sent, we have that

$$\varepsilon = \frac{I_r}{I_s}$$

Given that the rate of additional information sent is proportional to the difference between the quantity of information received and the quantity of information to be sent as given by

$$I_r(t) - I_s(t)$$

We can define the rate of information sent as

$$\frac{dI_s}{dt} = \lambda\left(I_r(t) - I_s(t)\right) = -\lambda(1-\varepsilon)I_s(t)$$

The constant λ is related to the time constant required to complete the encode-transmit-decode communication process and can be arbitrarily set to one. Similarly, for purposes of this example, the total quantity of information to be sent can be normalized, so that,

$$t \to \infty,\ I_s(t) \to 1$$

In terms of the probability that information will not be received, where $p_{ij} = 1 - \varepsilon$,

$$\frac{dI_s}{dt} = -p_{ij} I_s(t)$$

The solution of this differential equation is exponential,

$$I_s = -\exp\left(-p_{ij} t\right) + C$$

Given that, at time t=0, $I_s = 0$ we have that $C = 1$. Using the previously derived linear expression for the probability of information transmission loss as related to the utility of media, we can express the above solution in terms of the media utility,

$$I_s = 1 - \exp\left(\left(\frac{U_{ij} - 1}{5} - 1\right) t\right)$$

Thus we have that the rate of information transfer is exponentially related to the utility of media and behaves in a response characterized by Figure 5.4. Since $\lambda = 1$, each iteration of the communication process occurs in exactly one unit of time.

Returning to the Work Transformation Matrix, the probabilities used in the WTM define the likelihood that executing a particular task will produce added downstream work. Thus, at any given instant, once a unit of work is added to the system, the WTM computes the sum of subsequent work that is performed downstream in the next iteration as a result of the probabilities for work performed resulting in rework.

Drawing an analogy with the communication example, after exactly one iteration, a quantity of information I_1 is sent at $t = 0$, the quantity of information expected to be resent in the next iteration I_2 is

$$I_2 = I_1\left(1 - \exp\left(-p_{ij}\right)\right) = I_1\left(1 - \exp\left(\left(\frac{U_{ij} - 1}{5}\right) - 1\right)\right)$$

Therefore, the ratio of the additional information to the original information supplied is exponentially related to the probability that information will be lost in the communication process as calculated from the media utilities. This information ratio is given by

$$\frac{I_1 - I_2}{I_1} = \exp\left(\frac{U_{ij} - 1}{5} - 1\right)$$

This expression defines the percent of additional information in the subsequent iteration of the communication process arising from the initial act of introducing information to the communication process. While similar to the probabilities A_{ij} as used in the WTM matrix, the above relationship does not consider the preferences of individuals with regard to the additional information required in order to make a decision. Sometimes individuals will feel

comfortable making decisions with incomplete information. Such behavior can be associated with the uncertainty avoidance preferences of the individuals.

5.2.3 Concurrence Relationships

Ford and Sterman introduced the concept of concurrence relationships in the analysis of dynamic modeling of product development processes (Ford, Sterman, 1997). Concurrence relationships define the degree to which tasks occur sequentially or concurrently. Essentially, a concurrence relationship states that a downstream activity can only be completed once a given percentage of a prior activity has been completed. Communication processes with incomplete or partial transmittal of information to downstream activities share the characteristic of a concurrence relationship in that the ability to make a downstream decision is predicated on the availability of a certain percentage of required upstream information. Figure 5.5 shows an example of a concurrence relationship where the probability that information is available is on the x-axis and the probability that a decision will be made is on the y-axis. Note that in Figure 5.5 the x-axis has been scaled so that the probability that information is available corresponds to the media utilities. This translation is based on the relationship between media utility and efficiency of the medium as derived in Section 5.1.

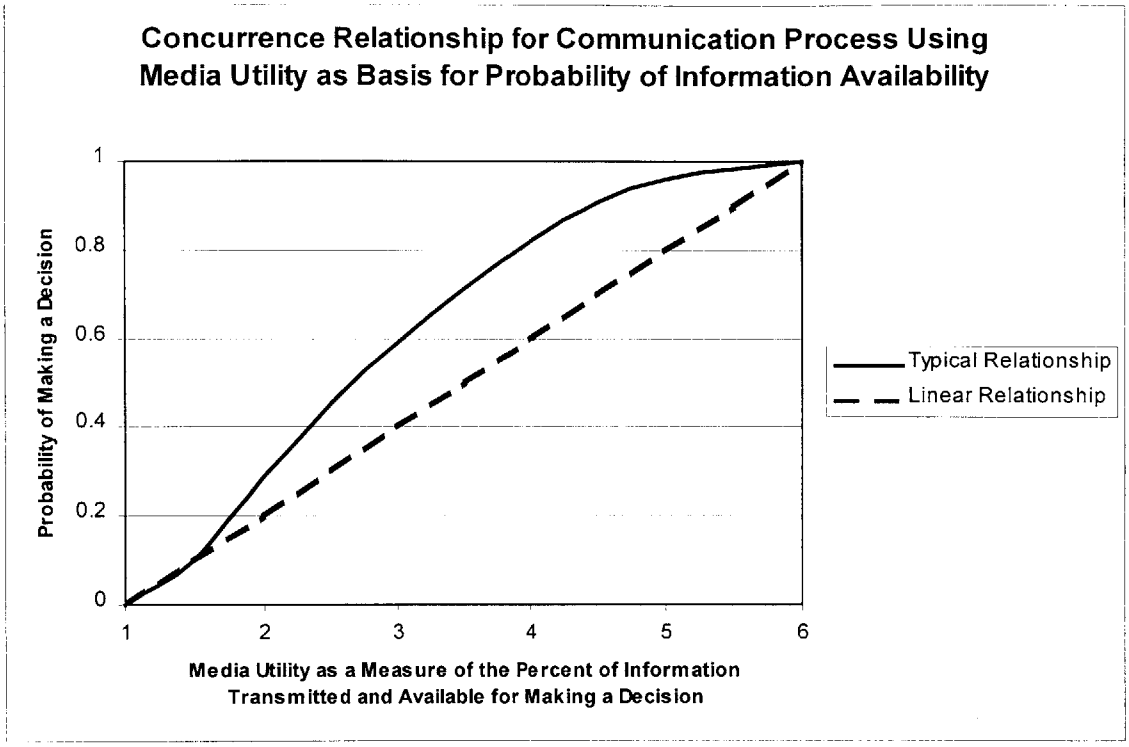

Figure 5.5: Concurrence Relationship

Adapted from Ford and Sterman, 1997

If all upstream information is required, then the concurrence relationship will be linear. Typically, the concurrence relationship will be nonlinear and take the form of the curve as shown in Figure 5.5. This curve implies that individuals are likely to make decisions even in the presence of incomplete information. Such an assumption is usually valid, since the decision process is ordinarily limited in time due to schedule pressures that do not afford opportunities for unlimited debate and complete convergence of information across the team.

The curve shown in Figure 5.5 can be expressed as the sum of two exponential functions,

$$P_{ij} = \frac{1}{2} + \frac{1}{2}\left(\exp\left(\alpha \frac{U_{ij} - U_{\max}}{U_{ij} - U_{\min}} \right) - \exp\left(\beta \frac{U_{ij} - U_{\min}}{U_{ij} - U_{\max}} \right) \right)$$

This expression was derived using the appropriate scaling to transform the probability of complete information being transmitted to the functions based on the utility of media. This scaling is achieved by substituting the values for the limits of the utility scale used in this analysis, namely $U_{max} = 6$ and $U_{min} = 1$. Substituting these values for the range of utilities used in the study, the expression satisfies the following boundary conditions,

1. For media with a utility of equal to one, no information is transmitted (zero efficiency) and the probability of making a decision is zero, i.e.,

$$P_{ij} = 0 \; when \; U_{ij} = U_{\min} = 1$$

2. For media with a perfect utility of six, all information is efficiently transmitted and the probability for making a decision is one, i.e.,

$$P_{ij} = 1 \; when \; U_{ij} = U_{\max} = 6$$

In order to determine the appropriate values for α and β, we investigate the behavior of the derivative of the function. Upon substituting for U_{max} and U_{min} and differentiating, we have the expression,

$$\frac{dP}{dU} = \frac{\alpha}{2}\left(\frac{5}{(U-1)^2}\right)\exp\left(\frac{U-6}{U-1}\right) + \frac{\beta}{2}\left(\frac{5}{(U-6)^2}\right)\exp\left(\frac{U-1}{U-6}\right)$$

We observe the following limits on the derivative as the utility approaches the maximum and minimum values,

$$U \to 6, \frac{dP}{dU} \to \frac{\alpha}{10} \quad and \quad U \to 1, \frac{dP}{dU} \to \frac{\beta}{10}$$

The other point of interest in defining the relationship between α and β is the mid-point at which $U = ½ (U_{max} + U_{min}) = 3.5$, where

$$\left.\frac{dP}{dU}\right|_{U=3.5} = \frac{\alpha}{2.5}e^{-1} + \frac{\beta}{2.5}e^{-1} = \frac{(\alpha+\beta)}{2.5e}$$

We can arbitrarily define the derivative at the midpoint derivative to account for varying degrees of the effects of uncertainty avoidance preferences. Decreasing the derivative is equivalent to increasing the risk tolerance and associated uncertainty preferences. However, for simplicity, we assume that the derivative at the midpoint is the same as the slope of the linear concurrence relationship in Figure 5.5. Thus, we have that,

$$\left.\frac{dP}{dU}\right|_{U=3.5} = \frac{\alpha+\beta}{2.5e} = 0.2 \quad or \quad \alpha+\beta = 0.5e = 1.35914$$

By adjusting values of α given the constraint above, we can modify the curve to account for increasing correspondence relationships. For purposes of this analysis, we use the assignment of values for the coefficients in the concurrence relationship as shown for the actual curve in Figure 5.5, namely,

$$\alpha = 0.27 \qquad \text{and} \qquad \beta = 1.089$$

Note that the concurrence relationship used also is consistent with the more conservative linear relationship for very low media utility values.

Thus, the appropriate interpolation to use within the communication WTM for the probability of resending information is not a linear interpolation based upon the utilities as discussed earlier, but it is exponential. Furthermore, this relationship is associated with the concurrence relationship as discussed herein. Therefore, subsequent WTM analysis in Section 5.3 uses the matrix probabilities A_{ij} based upon the media utilities of the form,

$$A_{ij} = 1 - P_{ij} = \frac{1}{2} + \frac{1}{2}\left(\exp\left(\alpha \frac{U_{ij} - 6}{U_{ij} - 1} \right) - \exp\left(\beta \frac{U_{ij} - 1}{U_{ij} - 6} \right) \right)$$

This probability (A_{ij}) defines the likelihood that the act of sending a unit of information from the i-th individual to the j-th member of the team will result in additional information having to be processed in the subsequent iteration by the j-th person as a result of inefficiencies in the communication process due to limitations of the media and other cultural and language effects incorporated into the media utilities. This analysis assumes that, with the exception of media efficiency and the aforementioned communication barriers; there are no other sources of information loss such as the lack of sufficient information to begin with associated with the communication process studied.

5.3 Work Transformation Analysis

WTM provides a means to determine rates of convergence of information processing, which in turn indicates the speed with which a team might reach consensus. The work transformation matrix A is populated with probabilities that a task transmitting a unit of information will generate significant information processing in other dependent tasks. The probability of accurately processing a unit of information P_{ij} is a function of U_{ij} the utility of

the media, with noise factors like barriers and transmission problems factored in. The probability of rework or having to process additional information is defined as

$$A_{ij} = 1 - P_{ij}$$

5.3.1 Scenario Description

A scenario analysis was performed to test the WTM methodology. A scenario analysis allows the flexibility of changing various parameters and exploring the methodology in depth. The scenario used to demonstrate the WTM methodology consists of a globally dispersed team with seven members in four locations. Individual team members are denoted by capital letters A through G. The breakdown is as follows: Japan – 2 members (G,F), Germany – 1 member (E), U.K – 2 members (C,D) and North America – 2 members (A,B). It is assumed that this team is fully networked in that they all can communicate with each other at will. This results in a fully populated NDSM as shown in Table 5.2. All off diagonal values of matrix A represent probabilities of additional information processing due to noise such as cultural and language barriers and are derived from media utilities calculated in Chapter 4. Table 5.2 shows the interaction matrix (DSM) between team members and the associated communication probabilities for the interactions. Each value is calculated based on the media utilities derived in Chapter 4 using the following equation from in Section 5.2:

$$A_{ij} = 1 - P_{ij} = \frac{1}{2} + \frac{1}{2}\left(\exp\left(\alpha \frac{U_{ij} - 6}{U_{ij} - 1}\right) - \exp\left(\beta \frac{U_{ij} - 1}{U_{ij} - 6}\right)\right)$$

We can use the interaction matrix to study the effects of language and culture for different communication media by studying the properties of the matrix when probabilities are calculated using various utilities of media both with and without culture and language effects.

Table 5.2 Team Interactions Matrix (DSM)

		Team Interaction Scenario						
		Japan		Germany	U.K.		N.A.	
		G	F	E	C	D	A	B
Japan	G	A_{GG}	A_{GF}	A_{GE}	A_{GC}	A_{GD}	A_{GA}	A_{GB}
	F	A_{FG}	A_{FF}	A_{FE}	A_{FC}	A_{FD}	A_{FA}	A_{FB}
Germany	E	A_{EG}	A_{EF}	A_{EE}	A_{EC}	A_{ED}	A_{EA}	A_{EB}
U.K.	C	A_{CG}	A_{CF}	A_{CE}	A_{CC}	A_{CD}	A_{CA}	A_{CB}
	D	A_{DG}	A_{DF}	A_{DE}	A_{DC}	A_{DD}	A_{DA}	A_{DB}
N.A.	A	A_{AG}	A_{AF}	A_{AE}	A_{AC}	A_{AD}	A_{AA}	A_{AB}
	B	A_{BG}	A_{BF}	A_{BE}	A_{BC}	A_{BD}	A_{BA}	A_{BB}

As previously mentioned, the probability (A_{ij}) defines the likelihood that the act of sending a unit of information from the i-th individual to the j-th member of the team will result in additional information having to be processed in the subsequent iteration by the j-th person as a result of inefficiencies in the communication process due to limitations of the media and other cultural and language effects incorporated into the media utilities. Main diagonal values A_{GG}, A_{FF}, A_{EE}, A_{CC}, A_{DD}, A_{AA} and A_{BB} are set to zero. Table 5.3 below shows the actual values used in the analysis of team for the case where only E-Mail is used in the presence of language differences.

Table 5.3 "A" Matrix – Email Media and Language Differences

		Email and Language Scenario						
		Japan		Germany	U.K.		N.A.	
		G	F	E	C	D	A	B
Japan	G	**0.0000**	0.0201	0.0319	0.0256	0.0256	0.0242	0.0242
	F	0.0201	**0.0000**	0.0319	0.0256	0.0256	0.0242	0.0242
Germany	E	0.0371	0.0201	**0.0000**	0.0211	0.0211	0.0201	0.0201
U.K.	C	0.0256	0.0256	0.0311	**0.0000**	0.0201	0.0221	0.0221
	D	0.0256	0.0256	0.0311	0.0201	**0.0000**	0.0221	0.0221
N.A.	A	0.0281	0.0281	0.0264	0.0225	0.0225	**0.0000**	0.0201
	B	0.0281	0.0281	0.0264	0.0225	0.0225	0.0201	**0.0000**

5.3.2 WTM Analysis Procedure

The matrix A can be decomposed into the product of a diagonal matrix containing eigenvalues and a matrix of corresponding eigenvectors as represented by the following equation:

$$A = S \Lambda S^{-1}$$

where Λ is a diagonal matrix of the eigenvalues of the matrix A and S represents the corresponding eigenvector matrix. For A to have linearly independent eigenvectors, the eigenvector matrix S must be invertible. For a matrix to be invertible, it is sufficient but not necessary that none of the eigenvalues are repeated (Strang, 1976). Next, we introduce the vector w_n referred to as the work vector. Each element of the work vector represents the amount of information to be processed at the end of each iteration. At the beginning of the

iteration process, the work vector is represented by w_o as a vector of ones, indicating that the initial information to be processed by each member of the team corresponds to exactly one unit of information. Based on the assumption that information processing by a member results in additional information processing by all dependent members, each iteration of information processing results in the following change in the work vector w_n:

$$w_{n+1} = A\, w_n$$

Since the entries in matrix A represent the probability that sending a unit of information from the i-th individual to the j-th member of the team will result in additional information having to be processed in the subsequent iteration by the j-th person. The iterative nature of the process allows the work vector w_n to be represented as follows:

$$w_n = A^n\, w_o$$

Summing the work vectors for N iteration of the process results in the total work vector W which is expressed as:

$$W = \sum_{i=0}^{N} w_i = \sum_{i=0}^{N} A^i\, w_o = \left(\sum_{i=0}^{N} A^i \right) w_o$$

The total work vector W represents amount of processing that has to be completed when information is input to the process.

The powers of matrix A can also be expressed using the eigenvalue and eigenvector matrices:

$$A^n = S\, \Lambda^n\, S^{-1}$$

Through subsequent iterations, the process converges if the value of the largest eigenvalue is less than one. This implies that, as the number of iterations N increases to infinity, the total work vector W remains bounded. As the number of iterations N approaches infinity, the limit of the summation of the diagonal matrix of eigenvalues can be expressed as:

$$\lim_{N\to\infty}\sum_{i=0}^{N}\Lambda^{i} = (1-\Lambda)^{-1}$$

Since the total work vector W can be expressed as,

$$W = \left(\sum_{i=0}^{N} A^{i}\right) w_o = S\left(\sum_{i=0}^{N}\Lambda^{i}\right) S^{-1}\, w_o$$

from the above expression, as N approaches infinity we obtain:

$$W = S(I-\Lambda)^{-1}\, S^{-1}\, w_o$$

The total work vector representing the total amount of information processing required by each member converges only when every eigenvalue is less than one.

5.3.3 Results of WTM Analysis of Communication Matrix

WTM analysis was applied to the following six scenarios in the context of a global team interaction.

1. Email only with Language differences (E/L)

2. Face-to-face only with Language differences (F/L)

3. Voice only with Language differences (V/L)

4. Email only with Culture differences (E/C)

5. Face-to-face only with Culture differences (F/C)

6. Voice only with Culture differences (V/C)

In the above scenarios, the analysis is limited to the assumption that only one media type is used in this communication. While global teams might use a combination of several different media, this analysis considers only the occurrence of a single event where a unit of information or knowledge is introduced to the team. For purposes of this study, a unit of knowledge or information is arbitrarily defined as equivalent to a statement of fact or metaphorical concept (explicit) or a statement of opinion or sensation (tacit). In this scenario, it is entirely plausible that only one media type is used to communicate such a unit of information. Also, the exact content or nature of the information conveyed is not considered, only that an instance of a communication process involves the transmittal of one such "unit" of information.

The process for analyzing the WTM is as follows:

1. Compute the matrix $A_{ij} = 1 - P_{ij}(U_{ij})$ using the utilities for media with either language or culture effects as derived in Chapter 4.

2. Derive the eigenvalues and eigenvectors for the matrix. This step was achieved using the MathWorks Matlab v11 software.

3. Calculate the total work vector $W = S\,(I - \Lambda)^{-1}\,S^{-1}\,w_o$

Complete results for all scenarios are included in Appendix VI. As an example, results of the Scenario 1, Email/Language are detailed as follows:

Email-Language Work Transformation Matrix

$A =$

0	0.0608	0.0689	0.0648	0.0648	0.0638	0.0638
0.0608	**0**	0.0689	0.0648	0.0648	0.0638	0.0638
0.0721	0.0721	**0**	0.0615	0.0615	0.0608	0.0608
0.0648	0.0648	0.0684	**0**	0.0608	0.0623	0.0623
0.0648	0.0648	0.0684	0.0608	**0**	0.0623	0.0623
0.0664	0.0664	0.0653	0.0626	0.0626	**0**	0.0608
0.0664	0.0664	0.0653	0.0626	0.0626	0.0608	**0**

Email-Language Eigenvectors Matrix

$S =$

-0.3792	0.3809	-0.0357	-0.0500	-0.7071	0.1700	0.1902
-0.3792	0.3809	-0.0357	-0.0500	0.7071	-0.1700	-0.1902
-0.3809	-0.7553	0.5700	-0.4034	0.0000	-0.0000	-0.0000
-0.3763	0.1884	-0.5202	-0.3001	0.0044	0.5585	0.2472
-0.3763	0.1884	-0.5202	-0.3001	-0.0044	-0.5585	-0.2472
-0.3769	-0.1848	0.2562	0.5710	0.0031	0.3989	-0.6346
-0.3769	-0.1848	0.2562	0.5710	-0.0031	-0.3989	0.6346

Email-Language Eigenvalue Matrix

$\Lambda =$

0.3854	0	0	0	0	0	0
0	**-0.0736**	0	0	0	0	0
0	0	**-0.0666**	0	0	0	0
0	0	0	**-0.0628**	0	0	0
0	0	0	0	**-0.0608**	0	0
0	0	0	0	0	**-0.0608**	0
0	0	0	0	0	0	**-0.0608**

Email-Language Total Work Vector

$W =$

1.6294
1.6294
1.6323
1.6240
1.6240
1.6251
1.6251

For a process to converge, the value of the largest eigenvalue must be less than one. An eigenvalue greater than one indicates that a member processing one unit of work during an iteration stage will result in the creation of more than one unit of information processing in the future. This corresponds to an unstable situation where the work vector grows unbounded as the number of iterations increase. The process in such a case is divergent. A divergent communication process is one where there is an explosion in the amount of information created and processed such that it is impossible to obtain enough useful information to reach a consensus or make a decision.

The relative contribution of each individual team member to the total process is indicated by the eigenvector corresponding to the eigenvalue associated with that particular member. The magnitude of the eigenvalue attributed to a team member characterizes the geometric rate of convergence of communication process for that individual. The larger the eigenvalue, the slower the rate of convergence and the greater the number of iterations required. Tables 5.4 and 5.5 display the results of the work transformation analysis for different media and communication barriers.

Table 5.4 Scenario Results for Maximum Eigenvalues (Rate of Convergence)

	Scenario					
	Email/ Language	Face-to-Face/ Language	Voice Language	Email/ Culture	Face-to-Face/ Culture	Voice/ Culture
Highest Eigenvalue	0.3854	0.2008	0.4023	0.4631	0.2516	0.4684

Table 5.5 Scenario Results for Total Work Vector

		Scenario					
		Email/ Language	Face-to-Face/ Language	Voice Language	Email/ Culture	Face-to-Face/ Culture	Voice/ Culture
Total Work Vector	G	1.6294	1.2529	1.6756	1.8273	1.3181	1.8485
	F	1.6294	1.2529	1.6756	1.8273	1.3181	1.8485
	E	1.6323	1.2554	1.6795	1.8942	1.3525	1.9095
	C	1.6240	1.2487	1.6693	1.8737	1.3421	1.8910
	D	1.6240	1.2487	1.6693	1.8737	1.3421	1.8910
	A	1.6251	1.2497	1.6707	1.8766	1.3439	1.8939
	B	1.6251	1.2497	1.6707	1.8766	1.3439	1.8939

In analyzing the results, we can draw conclusions on both the convergence of the communication process and the effect of increasing the size of team.

Convergence

Convergence can be illustrated by the following example. Team member A sends a unit of information consisting of ten words to member C. Given that the probability of successfully transmitting information from A to C is 0.6, C only receives six out of the ten words originally transmitted, having lost four words in the transmission process. C replies to A

with feedback requesting a re-transmittal of the information. This is classified as one iteration. On the second transmission C again only receives six words, which may differ from the first six. However, C only has to process the subset of words not included in the first set of six received in the previous transmission. C is able to piece together more information by combining the output of these two transmissions, thus inferring more of the original message from the two incomplete transmissions. The rate at which C can put together the pieces of information and gain an understanding of the original message is the rate of convergence. The total effort C has to expend to reach this point is equivalent to the total work vector.

The six scenarios evaluated produced the following results: Face-to-face media in the presence of language differences (F/L) convergences the fastest (maximum eigenvalue = 0.2008), whereas voice media in the presence of cultural difference took the longest time to reach convergence (maximum eigenvalue = 0.4684). In the presence of culture and language differences, the use of face-to-face media promotes faster convergence. These findings can be attributed to the fact that utility rankings for face to face media in the presence of either language or culture differences consistently ranked higher than utility rankings for email and voice (Chapter 4). One important caveat to these results is that the high utility rankings for face-to-face are most likely biased due to the sample of the survey respondents that consisted of a large percentage of English-speaking expatriate employees. Other research and experience suggests that email may have higher utilities for some language and cultural differences. High media utilities translate to a lower probability for loss of information during transmission and thus a reduced likelihood of information processing iterations. Figure 5.6 depicts a ranking of the rates of convergence for each of the six scenarios tested.

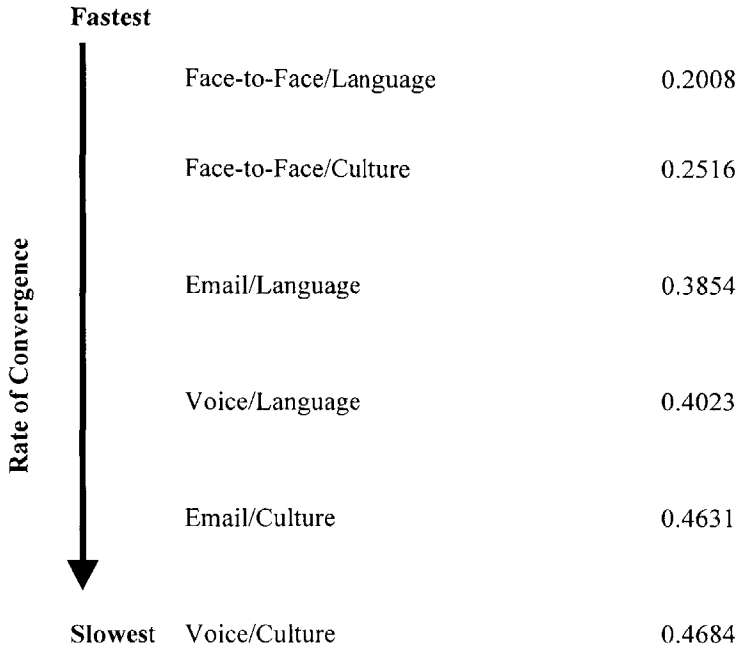

Figure 5.6 Rates of Convergence

Total Work Done

The work vector depicts the total amount of processing of one unit of information necessary for a team to converge to reach a consensus. The faster the convergence rate, the less the amount of total information processing required. The results from the WTM analysis show the work vector with the lowest value is associated with face-to-face media while the other two media produced higher total work vectors. This implies that with voice and email media, information processing is more likely to go through more iterations, causing more effort to be expended in the process. Results for the total work vector indicate that the rate of convergence is directly proportional to the total work expended in information processing. Figure 5.7 shows the largest component of the total work vector corresponding to each scenario studied.

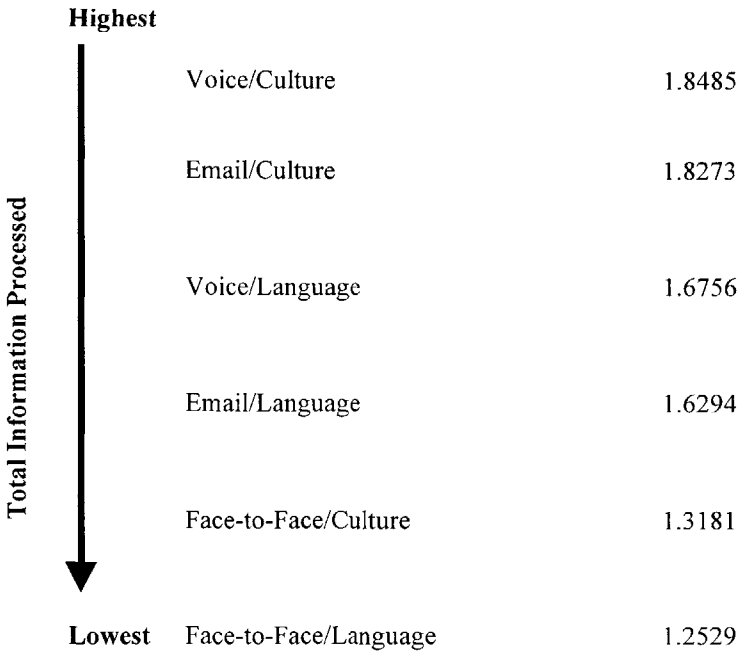

Figure 5.7 Largest Component of Total Work

Team Size

The scenario above was modified to study the effect of varying the size of the team. The size of the team was increased from seven to twelve, and then from twelve to fifteen. As the size of the team grew, the value of the maximum eigenvalue increased dramatically indicating a lower convergence rate and a slower process. The total work vectors also increased reflecting the increase in information processing effort. In the email/culture scenario, the value of the highest eigenvalue rose from 0.4631 to 0.7901 as the team size increased from seven to twelve, indicating that it took longer to converge or reach consensus. For a team size of fifteen the value rose to 0.9806, which is a value very close to one. These results demonstrate the convergence of the process is significantly impacted by the addition of team members. At a team size of fifteen, the process was very close to diverging. The total work vector increases proportionally to the increase in maximum eigenvalues.

Tables 5.5 and 5.6 show comparisons of the effect of team sizes on eigenvalues and total work vectors for the email/culture scenario, respectively. Figure 5.8 depicts the divergence of the communication process as the team size grows.

Email-Culture Scenario

Table 5.6 Team Size Versus Maximum Eigenvalues

	Team Size		
	7	12	15
Largest Eigenvalue	0.4631	0.7901	0.9806

Table 5.7 Team Size Versus Total Work Vector

	Team Size		
	7	12	15
Work Vector	1.8273	4.8210	53.3622
	1.8273	4.8210	53.3622
	1.8942	4.7469	51.5322
	1.8737	4.9023	54.0081
	1.8737	4.9023	54.0081
	1.8766	4.7009	50.4991
	1.8766	4.7009	50.4991
		4.7009	50.4991
		4.7009	50.4991
		4.7009	50.4991
		4.7009	50.4991
		4.7009	50.4991
			50.4991
			50.4991
			50.4991
			50.4991

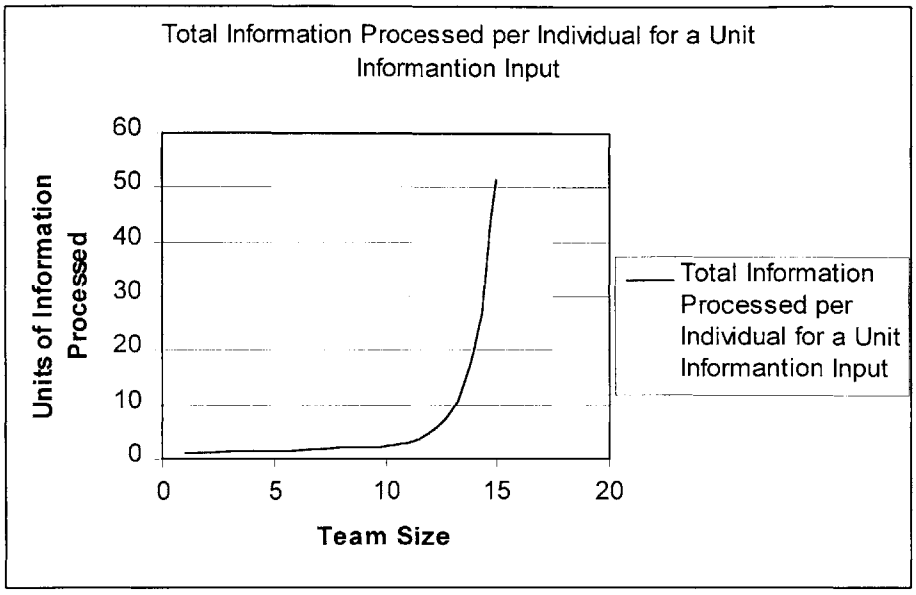

Figure 5.8 Team Size Versus Total Work Vector

The effect of increasing the size of the team can be illustrated by the following example. A team member sends a unit of information to a fifteen-person team. Another member sends feedback requesting additional information but the request goes to the whole team because the "Reply All" feature is used. All other team members reply to the request and again reply to all other members. This can go on for several iterations and the volume of information exchange grows unbounded. One unit of information can result in an exponentially large increase in the total information processed. This process, if left unchecked, will continue iterating and potentially diverge, meaning that the team is confounded by this one unit of information and will not reach consensus on it.

Divergent Processes and Self-Selection

Divergent processes can lead to frustration for team members. Some members get frustrated at the chaotic nature of the process as more information is fed into the system, while others may be frustrated at their inability to extract the required information from the process and

close the information gap. This frustration could have several consequences, the most likely being a withdrawal from the process. Withdrawal in this case is to cease requesting additional information because the member chooses to work with existing information or because the member is overwhelmed by the amount of information to be processed. Such self-selected withdrawal among various members from the team process will force artificial convergence of a divergent process.

We characterize this self-selection process as an artificial "tearing" of the DSM. Tearing is a process where tightly coupled tasks are decoupled to reduce the number of iterations and produce a better sequence of tasks. Tearing involves selectively eliminating the interactions that produce iterations. In the team process, self-selection of team members due to frustration effectively "reduces" the size of the team, allowing the team to reach consensus. Figure 5.9 below models the dynamics of this process.

This model can be explained as follows: the sender transmits some desired amount of information to the receiver through a specific medium. Due to noise in the transmission, some of the information is lost and incomplete information is received. The receiver perceives this gap in information and requests additional information from the sender. The sender resends the same information but it still suffers similar losses due to noise in the transmission channel. The receiver again gets incomplete information. Depending on the number of iterations of this process, the person on the receiving end could get frustrated with the process. As this frustration increases, the willingness to work with less or incomplete information increases because the perceived cost of acquiring the information exceeds the benefit gained from the information. Working with this incomplete information creates the

perception of a reduction in the information gap, which subsequently leads to a reduction in feedback and requests for additional information.

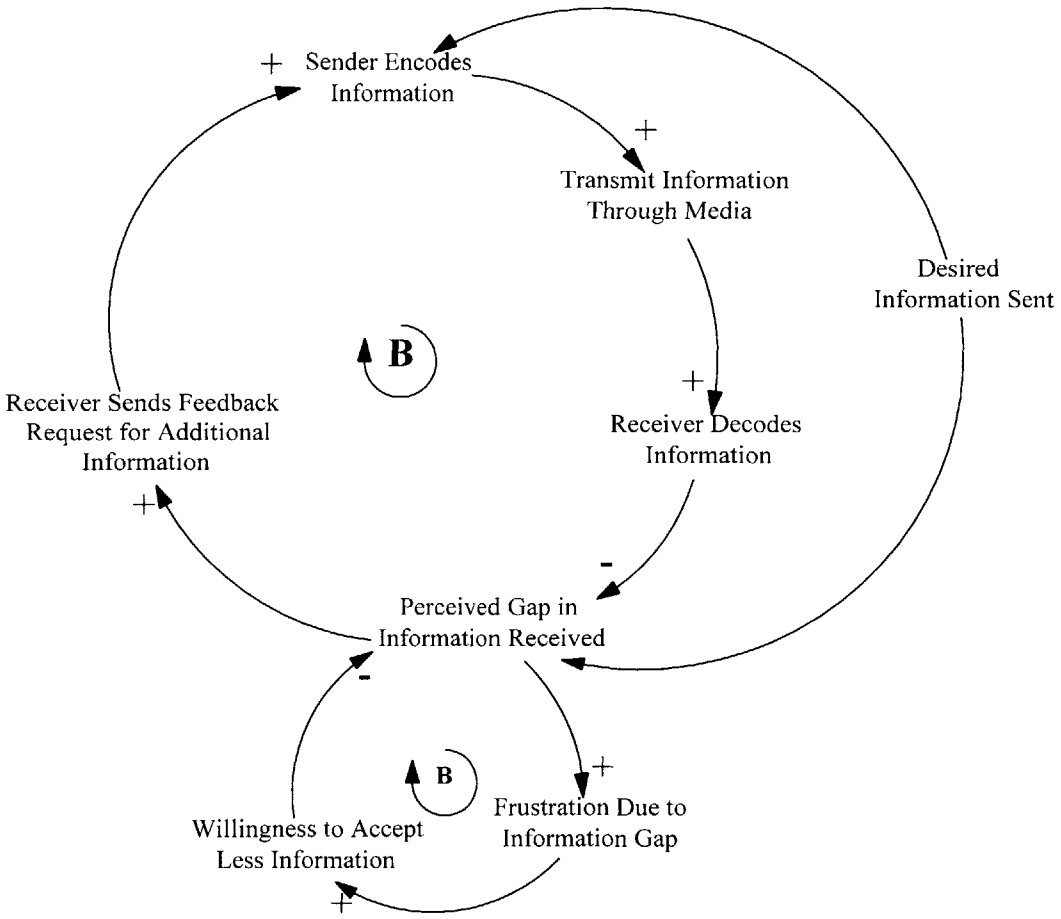

Figure 5.9 Team Dynamics and Divergent Communication Processes

Self-Selection and Culture

Cultural factors might provide some insights into which members of a team will be most likely to artificially "tear" themselves out of the team process. The most prominent cultural factors are low uncertainty avoidance and high power distance (Hofstede, 1980).

Low Uncertainty Avoidance

This dimension deals with the degree of tolerance for ambiguity. Since low uncertainty avoidance cultures are more tolerant of ambiguity, they are more willing to accept incomplete information and very likely to cease requesting additional information as their frustration with the information gap grows. They will attempt to work with what little information they have and not bother to process the barrage of information coming from the divergent process.

Large Power Distance

This dimension deals with the extent with which less influential members accept or expect power to be equally distributed As the communication process diverges due to the excessive amounts of information being input into the system, there is a probability that people from large power distance cultures will withdraw from the team interaction because the process becomes overpowering and outside their sphere of control. They will likely step back and allow more powerful or vocal members of the team resolve the process. This reaction is similar to members with significant language problems. As more information is input into the system, their ability to process it is reduced due to language difficulties and this might force them to withdraw from the process.

5.4 Summary of WTM Analysis

Results of the WTM analysis prove that it is a useful method for analyzing communication in teams and could probably be extended to other team processes. The probability that communication within a team will require repeated iterations of processing is a function of

the learning that takes place and the concurrence relationship associated with the quantity of information necessary to make decisions or reach a consensus. The analysis also demonstrated a method for characterizing uncertainty avoidance in the concurrence relationship.

Team size can significantly impact convergence of information processing. The larger the team, the longer it takes to achieve convergence. Adding more members to a team can cause overall divergence of the communication process and result in the inability of the team to achieve consensus.

Artificial "tearing" in teams through self-selection can occur randomly when the communication process diverges. Cultural factors such as the uncertainty avoidance and power distance relationships play a significant role in the like likelihood that certain team members will be predisposed to self-tearing in a divergent communication process. Management can enforce "tearing" by strategically structuring the product development process and communication environment to reduce the likelihood of unstable communication processes.

6.0 Conclusion

Effective communication is vital to the success of teams, whether co-located or globally dispersed. Nevertheless, the literature search revealed that virtual teams are not only confronted by the same challenges facing traditional teams, they must also contend with the difficulties associated with communication when separated in space and time. Results of the literature search also confirmed the significance of cultural and language barriers in the communication among globally dispersed teams. Furthermore, while organizational culture has significant implications for teams in general, global teams must manage the added barriers resulting from other factors arising due to differences in national culture.

Interviews were useful for defining the critical concerns of global teams and identifying communication needs. The combination of structured interviews with metaphor elicitation techniques provided a rich understanding of the needs that extend to a variety of communication environments beyond just those studied. The profound understanding of needs was essential in order to develop efficient survey instruments capable of providing the required quantitative measurements necessary for this research.

The surveys produced a rich set of data useful for assessing the relative importance of communication needs and the utility of media in satisfying these needs. The surveys were also effective in quantifying the effects of culture and language barriers encountered in global team communications. Statistical analysis of the survey data provided the basis for the subsequent numerical analysis using the Design Structure Matrix methodology.

A conceptual framework for communication was developed based on system dynamics and the concepts of the learning curve and concurrence relationships. It was also shown how this framework could accommodate inclusion of the cultural factors of uncertainty avoidance and power distance relationships which impact decision-making and consensus processes in teams. A form of numerical DSM known as the Work Transformation Matrix was employed to study the effects of different media and communication barriers. The analysis was further extended to demonstrate that increasing team size could result in divergent communication processes. Such processes, if left unchecked, can cause self-selected withdrawal of individuals from the decision making process. The study concludes that more effective communication processes can be achieved by actively managing the communication flow to avoid unstable or unpredictable team behavior.

Findings can be summarized as follows:

- Fundamental needs that apply to most communication environments and media include user friendliness, privacy and ability to support feedback.

- The needs for Tacit-to-Tacit, Tacit-to-Explicit and Explicit-to-Tacit modes of communication can be aggregated and analyzed concurrently.

- Different modes of communication can be associated with different stages of the product development cycle.

- High utility rankings of face-to-face media suggest that teams have a strong preference for face-to-face interactions.

- Communication has to be actively managed by applying appropriate team structures, team size and tearing strategies to ensure convergence is achieved.

Future Work

The work done in this thesis can be further extended as follows:

- Increasing the sample population can further explore the impact of functional culture on communication needs and media preferences. Areas of significant interest include the issue of expatriate employees.

- Extending the application of the concurrence relationship to categorize decision-making using quantified uncertainty avoidance and power distance relationships.

- Analysis of complete communication processes involving the simultaneous use of multiple media.

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Appendices

Appendix I - Global Teams Research Interview Questions

Appendix II – ZMET Interview Guide

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Appendix I - Global Teams Research Interview Questions

Name: _____ Date: _____
Title: _____

General Team Data

What is the purpose of the global team in which you participate?

What is the approximate size of the team?

- ❑ 2-7 members
- ❑ 8-14 members
- ❑ 15-25 members
- ❑ 25+ members

What is the level of geographic dispersion of the team?

Describe briefly your primary job responsibilities in the context of the global team.

Team Meetings

How often do you participate in global team meetings? What is the format for such meetings? What are some of the difficulties in participating in such meetings?

Do protocols exist for meetings and are they published, readily available? How well are they enforced?

Team Processes

Within the global team, are standard formats used for reporting information, making requests, etc., or are messages typically customized as necessary? Describe some examples.

What makes your global team perform well? What can be done to improve the way it works together?

Considering such things as business practices, processes and work hours, how has participation in your global team changed your way of doing business?

How is performance measured on the global team? How does this impact your own performance evaluation? What are the incentives for participation on your global team?

Communication Media

How do you typically communicate with other members of the team that are located at remote sites? What makes it difficult to convey information or other messages to remote sites?

Do you often find yourself going through the same communication channels, or do they vary widely depending upon the context?

When sending e-mail or other communication with a response lag-time, how does your expectation of response time compare with the actual response you get? In your opinion, how can such response time be improved?

When receiving e-mail messages from others, how do you decide which information is important and what you can ignore?

Can you describe a specific example of communication problems that you have encountered requiring face-to-face meetings to get the message across?

Organizational Learning

Where do you go to get information that you need to get your job done? Under what circumstances do you find it difficult to locate the information that you need?

Do you find that important information is delayed, lost or otherwise unavailable to you when you need it? Please describe some examples of when such problems occur.

Cultural Issues

Do you encounter language barriers in your communications? Describe them briefly.

What difficulties arising from cultural differences have you experienced in working with the global team?

Technology

What communication technologies do you currently use, such as e-mail, web documents, pagers, PDA's, etc.

When using the intranet to support your communication needs, is such technology primarily used for searching for information or conveying information to others?

What are your communication needs that you feel are not satisfied by existing technologies?

Follow-Up Question

Are there any questions you would have liked me to ask, or is there anything else that you would like to add?

Appendix II – ZMET Interview Guide

Motivation

Communication is reaching a level of capability that allows for nearly ubiquitous access to information and others through a variety of media. Nevertheless, despite the wide varieties of communication media available, individuals tend to prefer certain forms (e-mail, voice, fact-to-face, etc.) over others. Furthermore, as the menu of communication choices continues to grow with evolving technology, the complexity of the communication process increases, with people not being sure which medium is appropriate for a given message. Some, such as McLuhan [1], would argue that: "the medium is the message."

Objective

This study will interview individuals on the topic of communication, specifically to:

Understand if there is a difference between personal and business communication needs.
Identify areas where particular media fall short in satisfying customer needs.
Describe the selection criteria users apply to selecting certain media.

Introduction

First, let me thank you for taking the time to talk to me today. As you know, our team is trying to gain an in-depth understanding of what communication means to you and what you want from your choices of the many different ways to communicate that are available to you. Ultimately, we would like to understand what ideal communication means to you. We are conducting this research for the Listening to the Customer class, and your responses will be kept confidential. Now, let's begin by looking at the images you have brought with you.

ZMET Interview

Let's begin by looking at the images you have brought with you. For each image ask:

How does this image relate to communication?
Is this image simple or complicated?
Do the colors have any significance to you?
What kind of emotion does this image evoke?
Is there anything hidden in the image?

Imagine that the image continues in any direction and widen the frame of the picture in any direction. What do you see? What appears in the image when you expand it?

I want you to step into the picture. Place yourself in the image and describe what you see around you. What are you doing? What are you thinking? What are you feeling?

Are there any images that you could not locate that capture your feelings about communication? Describe the image, please, and tell me how it relates to communication.

Collect the images, shuffle and present to respondent face up. Select an image and ask the respondent (PERFORM THIS EXERCISE TWICE):

Which of the other images are most like the one I have selected? What is it about the second image that makes it most similar to the other one? How does [IDENTIFIED SIMILARITY] relate to communication?

Considering what you feel about communication as captured by the other images, which of the other images is most different from the one I have selected? What makes it different? How does [IDENTIFIED DIFFERENCE] distinguish the two relative to communication?

Sample interview questions

Give me an example of a typical problem that you have experienced when trying to communicate. Do you sometimes find it difficult trying to reach others when you need to? Which communication problems would you like to see fixed the most? Why?

What do you feel about your communication choices? What does access to communication mean to you?

What do you feel are some of the issues with communication? What is important to you? You seem to be talking more about (business/personal) communication needs. Does this also apply to your (personal/business) as well? How so? – OR – What's different about that?

When you need to get in touch with someone, how do you decide which form of communication to use? Does your choice of the form of communication typically agree with your desire to communicate in a certain way?

Where do you think communication is going in the 21st century? Do you feel comfortable with and prepared for it? Why or why not?

What is ideal communication to you? What needs to be improved to get us there?

[1] McLuhan, Marshall, Understanding Media, MIT Press, 1964

Appendix III - Communication Survey

Please complete the following survey. This survey is being administered as part of the research being performed for fulfillment of the degree requirements for the MIT System Design and Management Program. The objective of this survey is to understand the importance of specific attributes of communication media and rate the effectiveness of different media.

Your participation in this survey is greatly appreciated and is vital to the research being performed by the team. All responses will remain confidential and individual answers to any of the questions will not be disclosed. Responses to all questions are voluntary, and you may skip any questions that you do not feel comfortable answering.

Thank you for taking the time to complete this survey

Please indicate the typical frequency that you use the following media.

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly	Does Not Apply
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐
Other (specify)	☐	☐	☐	☐	☐	☐

If you selected other, please specify: **<Specify Other Here>**

How do you rate the following media as to their *Ease of Use*?

Please rate from 1=Difficult to Use to 6=Easy to Use.						
	1 Difficult To Use	**2**	**3**	**4**	**5**	**6 Easy To Use**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

How easy is it to *Personalize Messages* when using the following media?

Please rate each from 1=No Ability to Personalize to 6=Very Easy to Personalize messages.						
	1 No Ability to Personalize	**2**	**3**	**4**	**5**	**6 Very Easy to Personalize**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

How easy is it to obtain *Feedback* in order to assess the completeness and clarity of messages you send?

Please rate the following media from 1=Not Easy to get Feedback to 6=Very Easy to Get Feedback.						
	1 Not Easy To Get Feedback	**2**	**3**	**4**	**5**	**6 Very Easy To Get Feedback**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

Please rate the following media as to the level of *Security* they provide.

Please rate the following media from 1=Not Secure to 6=Very Secure.						
	1 Not Secure	**2**	**3**	**4**	**5**	**6 Very Secure**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

How easy is it to *Organize and Sort* (i.e., Categorize) information when using the following media?

Please rate from 1=Difficult to Categorize to 6=Easy to Categorize.						
	1 Difficult To Categorize	2	3	4	5	6 Easy To Categorize
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

Please rate the *Reliability* of the following media based on the level of support and services required for their use.

Please rate from 1=Not Reliable to 6=Very Reliable.						
	1 Not Reliable	2	3	4	5	6 Very Reliable
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

Consider a situation in which you are trying to *teach or explain how to perform a specific task that is not well documented* to others at different locations.

How often do find yourself in this type of situation?

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	Rank (1-6)	
Ease of Use	☐	Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest Situation: *Teach or explain how to perform a specific task that is not well documented* to others at different locations.
Ability to Personalize the Message	☐	
Feedback	☐	
Security of the Message	☐	
Information is Organized and Easy to Sort	☐	
Reliability of Service	☐	

Suppose you need to *describe the appearance, behavior or some other attribute of an object* to others at different locations.

How often do find yourself in this type of situation?

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	Rank (1-6)
Ease of Use	☐
Ability to Personalize the Message	☐
Feedback	☐
Security of the Message	☐
Information is Organized and Easy to Sort	☐
Reliability of Service	☐

Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest

Situation: *Describe the appearance, behavior or some other attribute of an object* to others at different locations.

Consider situations when you need to work together with others at different locations to *discuss concepts, share insights or brainstorm new ideas*.

How often do find yourself in this type of situation?

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	Rank (1-6)
Ease of Use	☐
Ability to Personalize the Message	☐
Feedback	☐
Security of the Message	☐
Information is Organized and Easy to Sort	☐
Reliability of Service	☐

Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest

Situation: *Discuss concepts, share insights or brainstorm new ideas* with others at different locations.

Suppose you need to *convey an established, well documented process or procedure* to others at different locations.

How often do find yourself in this type of situation?

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	Rank (1-6)
Ease of Use	☐
Ability to Personalize the Message	☐
Feedback	☐
Security of the Message	☐
Information is Organized and Easy to Sort	☐
Reliability of Service	☐

Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest

Situation: *Convey an established, well documented process or procedure* to others at different locations.

Thank you for completing this survey.

The following questions ask you about owning a Personal Digital Assistant (PDA), such as a Palm Pilot.

Do you currently use a PDA, and, if so, for how long have you been using such a device.

- ☐ Have been using a PDA for more than 2+ years
- ☐ Have been using a PDA for 1-2 years.
- ☐ Have been using a PDA for less than 1 year.
- ☐ Do not use a PDA.

How much did you pay, or if you do not already own a PDA, how much would you be willing to pay for a PDA device.

- ☐ More than $500
- ☐ Between $350 and $500.
- ☐ From $150 to $350.
- ☐ Under $150.
- ☐ Issued by company or received as a gift.

If you currently own a PDA, what is the typical frequency that you use it?

- ☐ Frequently on a daily basis
- ☐ Several times a week
- ☐ At least once a week
- ☐ Less than once a week

What is your sex/age group?

- ☐ Male
- ☐ Female

- ☐ Under 18 years
- ☐ 18-25 years
- ☐ 25-35 years
- ☐ 35-45 years
- ☐ 45+ years

Thank you for completing this survey.

Appendix IV - Communication Survey

MIT – Sponsor Company Global Team Forum

NOTE: This survey is a standard Word Document form. You may move between the response boxes using the <TAB> key or the mouse and scroll bar. Please enter an 'X' or click on any desired box to select. Brackets "<" and ">" indicate text boxes wherein you can type text. In order to type text, highlight (double-click) the text shown and type in your response.

Authors:

Viesturs Lenss vlenss@mit.edu

Gloria Pumpuni gpumpuni@mit.edu

Please complete the following survey. Your team is being asked to participate in research conducted by the MIT – Sponsor Company Forum on Globally Dispersed Teams. The objective of this survey is to understand the importance of specific attributes of communication media and understand the effectiveness of different media in the presence of barriers to communication associated with distance, language and culture.

Thank you for taking the time to complete this survey.
This survey should require approximately 30 minutes to complete.

The purpose of this survey is to research the factors leading to effective high performance, globally dispersed teams. This survey is part of the research being conducted to fulfill the thesis requirements for the MIT System Design and Management Program.

This survey is strictly voluntary and there is no obligation to answer every question; omit any questions you are unable or uncomfortable in answering. INDIVIDUAL RESPONSES WILL BE CONFIDENTIAL. The aggregated data will be used by the research team to identify areas of concern to members of geographically dispersed teams and for feedback to sponsoring companies for action planning to better support their geographically dispersed teams.

If you have any questions concerning this survey, please contact one of our research team members or use the e-mail addresses supplied above:

Janice Klein, MIT Sloan School of Management
Viesturs Lenss, MIT System Design and Management Fellow,
Gloria Pumpuni, MIT System Design and Management Fellow

Communication Survey

Please identify the globally dispersed team within Sponsor Company that you are a member of:

How often do you communicate with others on the team using each of the following media?

Please indicate the frequency that you typically use the following communication media.						
	Daily	**Weekly or Bi-Weekly**	**Monthly**	**Quarterly**	**Less than Quarterly**	**Does Not Apply**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐
Other (specify)	☐	☐	☐	☐	☐	☐

If you selected other, please specify: <Specify Other Here>

Please indicate which choice best represents your current job location?

Australia	**Japan**	**India**	**Asia (Other)**	**Brazil**	**Mexico/Other South America**	**France**	**Germany**	**United Kingdom**	**Europe (Other)**	**North America**	**Africa**
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

In general, how many people in total do you regularly communicate with at each location?

Please indicate the number of people that you regularly communicate with at each location.					
	None	**1**	**2**	**3**	**More than 3**
Australia	☐	☐	☐	☐	☐
Japan	☐	☐	☐	☐	☐
India	☐	☐	☐	☐	☐
Asia (Other)	☐	☐	☐	☐	☐
Brazil	☐	☐	☐	☐	☐
Mexico/Other South America	☐	☐	☐	☐	☐
France	☐	☐	☐	☐	☐
Germany	☐	☐	☐	☐	☐
United Kingdom	☐	☐	☐	☐	☐
Europe (Other)	☐	☐	☐	☐	☐
North America	☐	☐	☐	☐	☐
Africa	☐	☐	☐	☐	☐

What is the typical frequency of these communications?

Please indicate the frequency with which you communicate with other locations.						
	Does Not Apply	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	More than Quarterly
Australia	☐	☐	☐	☐	☐	☐
Japan	☐	☐	☐	☐	☐	☐
India	☐	☐	☐	☐	☐	☐
Asia (Other)	☐	☐	☐	☐	☐	☐
Brazil	☐	☐	☐	☐	☐	☐
Mexico/Other South America	☐	☐	☐	☐	☐	☐
France	☐	☐	☐	☐	☐	☐
Germany	☐	☐	☐	☐	☐	☐
United Kingdom	☐	☐	☐	☐	☐	☐
Europe (Other)	☐	☐	☐	☐	☐	☐
North America	☐	☐	☐	☐	☐	☐
Africa	☐	☐	☐	☐	☐	☐

How do you rate the following media as to their *Ease of Use*?

Please rate from 1=Difficult to Use to 6=Easy to Use.						
	1 Difficult To Use	**2**	**3**	**4**	**5**	**6 Easy To Use**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

How easy is it to *Personalize Messages* when using the following media?

Please rate each from 1=No Ability to Personalize to 6=Very Easy to Personalize messages.						
	1 No Ability to Personalize	**2**	**3**	**4**	**5**	**6 Very Easy to Personalize**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

How easy is it to obtain *Feedback* in order to assess the completeness and clarity of messages you send?

Please rate the following media from 1=Not Easy to get Feedback to 6=Very Easy to Get Feedback.						
	1 Not Easy To Get Feedback	**2**	**3**	**4**	**5**	**6 Very Easy To Get Feedback**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

Please rate the following media as to the level of *Security* (i.e., Confidentiality) they provide.

Please rate the following media from 1=Not Secure to 6=Very Secure.						
	1 Not Secure	**2**	**3**	**4**	**5**	**6 Very Secure**
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

How easy is it to *Organize and Sort* (i.e., Categorize) information when using the following media?

Please rate from 1=Difficult to Categorize to 6=Easy to Categorize.						
	1 Difficult To Categorize	2	3	4	5	6 Easy To Categorize
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

Please rate the *Reliability* (i.e., Dependability) of the following media based on the level of support and services required for their use.

Please rate from 1=Not Reliable to 6=Very Reliable.						
	1 Not Reliable	2	3	4	5	6 Very Reliable
E-Mail	☐	☐	☐	☐	☐	☐
Video	☐	☐	☐	☐	☐	☐
Face-to-Face Meeting	☐	☐	☐	☐	☐	☐
Voice/Telephone	☐	☐	☐	☐	☐	☐
Shared Documents (i.e. Web)	☐	☐	☐	☐	☐	☐
Fax	☐	☐	☐	☐	☐	☐
Text Pager	☐	☐	☐	☐	☐	☐

Consider a situation in which you are trying to *teach or explain how to perform a specific task that is not well documented* to others at different locations.

How often do find yourself in this type of situation?

How often are you typically faced with the need to *teach or explain how to perform a specific task that is not well documented* to others at different locations?					
	Daily	**Weekly or Bi-Weekly**	**Monthly**	**Quarterly**	**Less than Quarterly**
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.		
Media Attribute	**Rank (1-6)**	
Ease of Use	< >	Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest Situation: *Teach or explain how to perform a specific task that is not well documented* to others at different locations.
Ability to Personalize the Message	< >	
Feedback	< >	
Security of the Message	< >	
Information is Organized and Easy to Sort	< >	
Reliability of Service	< >	

Suppose you need to *describe the appearance, behavior or some other attribute of an object* to others at different locations.

How often do find yourself in this type of situation?

How often are you typically faced with the need to *describe the appearance, behavior or some other attribute of an object* to others at different locations?

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	Rank (1-6)
Ease of Use	< >
Ability to Personalize the Message	< >
Feedback	< >
Security of the Message	< >
Information is Organized and Easy to Sort	< >
Reliability of Service	< >

Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest

Situation: *Describe the appearance, behavior or some other attribute of an object* to others at different locations.

Consider situations when you need to work together with others at different locations to *discuss concepts, share insights or brainstorm new ideas*.

How often do find yourself in this type of situation?

How often are you typically faced with the need to *discuss concepts, share insights or brainstorm new ideas* with others at different locations?					
	Daily	**Weekly or Bi-Weekly**	**Monthly**	**Quarterly**	**Less than Quarterly**
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	**Rank (1-6)**	
Ease of Use	< >	Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest Situation: *Discuss concepts, share insights or brainstorm new ideas* with others at different locations.
Ability to Personalize the Message	< >	
Feedback	< >	
Security of the Message	< >	
Information is Organized and Easy to Sort	< >	
Reliability of Service	< >	

Suppose you need to *convey an established, well documented process or procedure* to others at different locations.

How often do find yourself in this type of situation?

How often are you typically faced with the need to *convey an established, well documented process or procedure* to others at different locations?

	Daily	Weekly or Bi-Weekly	Monthly	Quarterly	Less than Quarterly
Frequency	☐	☐	☐	☐	☐

How important are the following attributes to your choice of communication media when faced with situations as described above?

Please rank each attribute in order of preference from 1=Most important to 6=Least important.

Media Attribute	Rank (1-6)
Ease of Use	< >
Ability to Personalize the Message	< >
Feedback	< >
Security of the Message	< >
Information is Organized and Easy to Sort	< >
Reliability of Service	< >

Please Rank Each Attribute According to the Importance from 1=Highest, 6=Lowest

Situation: *Convey an established, well documented process or procedure* to others at different locations.

To what extent are communication difficulties the result of language? Please answer only for those locations that apply.

Please rate the level of communication difficulty that is the result of LANGUAGE by location From 1 = No Language Difficulty, to 6=Significant Language Difficulty						
	1 No Language Difficulty	**2**	**3**	**4**	**5**	**6 Significant Language Difficulty**
Australia	☐	☐	☐	☐	☐	☐
Japan	☐	☐	☐	☐	☐	☐
India	☐	☐	☐	☐	☐	☐
Asia (Other)	☐	☐	☐	☐	☐	☐
Brazil	☐	☐	☐	☐	☐	☐
Mexico/Other South America	☐	☐	☐	☐	☐	☐
France	☐	☐	☐	☐	☐	☐
Germany	☐	☐	☐	☐	☐	☐
United Kingdom	☐	☐	☐	☐	☐	☐
Europe (Other)	☐	☐	☐	☐	☐	☐
North America	☐	☐	☐	☐	☐	☐
Africa	☐	☐	☐	☐	☐	☐

Do you usually conduct business in your native language when communicating with other locations?

☐	I usually conduct business in my native language.
☐	I do not conduct business in my native language.

What is your native language: <Specify Language>

What is your perception of the level of cultural differences between your area and other locations? Please answer only for those locations that apply.

Please rate the level of CULTURAL difference as it exists according to location

From 1 = No Language Difficulty, to 6=Significant Language Difficulty

	1 No Difference	2	3	4	5	6 Significant Difference
Australia	☐	☐	☐	☐	☐	☐
Japan	☐	☐	☐	☐	☐	☐
India	☐	☐	☐	☐	☐	☐
Asia (Other)	☐	☐	☐	☐	☐	☐
Brazil	☐	☐	☐	☐	☐	☐
Mexico/Other South America	☐	☐	☐	☐	☐	☐
France	☐	☐	☐	☐	☐	☐
Germany	☐	☐	☐	☐	☐	☐
United Kingdom	☐	☐	☐	☐	☐	☐
Europe (Other)	☐	☐	☐	☐	☐	☐
North America	☐	☐	☐	☐	☐	☐
Africa	☐	☐	☐	☐	☐	☐

The following questions contain some statements. Please indicate the extent to which you agree or disagree with each statement.

Please answer as to whether you disagree or agree with the following statements:

Statement	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
People generally know what information they need, and will ask for it when necessary.	☐	☐	☐	☐
The performance of a team can be assessed using processes and metrics.	☐	☐	☐	☐
Teams that perform well are usually the result of strong leadership.	☐	☐	☐	☐
Employees can negotiate their objectives with management.	☐	☐	☐	☐
Employees should participate more in decisions made by management.	☐	☐	☐	☐
When a group cannot reach consensus, it is up to the leader to make the decision.	☐	☐	☐	☐
One should not complain to management about a problem when there are other ways to get around the issue.	☐	☐	☐	☐

How important are each of the following media attributes in reducing the effect of LANGUAGE differences? Please rate from 1=Not Important to 6=Very Important.

How important are the following media attributes in reducing the effects of LANGUAGE differences.

Please rate from 1=Not Important, to 6=Very Important.

	1 Not Important	2	3	4	5	6 Very Important
Ease of Use	☐	☐	☐	☐	☐	☐
Ability to Personalize the Message	☐	☐	☐	☐	☐	☐
Feedback	☐	☐	☐	☐	☐	☐
Security of the Message	☐	☐	☐	☐	☐	☐
Information is Organized and Easy to Sort	☐	☐	☐	☐	☐	☐
Reliability of Service	☐	☐	☐	☐	☐	☐

Please rank the following attributes of communication media as to how important each is in the presence of CULTURAL differences.

How important are the following media attributes in the presence of CULTURAL differences.

Please rate from 1=Not Important, to 6=Very Important.

	1 Not Important	2	3	4	5	6 Very Important
Ease of Use	☐	☐	☐	☐	☐	☐
Ability to Personalize the Message	☐	☐	☐	☐	☐	☐
Feedback	☐	☐	☐	☐	☐	☐
Security of the Message	☐	☐	☐	☐	☐	☐
Information is Organized and Easy to Sort	☐	☐	☐	☐	☐	☐
Reliability of Service	☐	☐	☐	☐	☐	☐

If you have any comments or would like to elaborate further upon your responses, please respond below.

<Enter Comments Here>

To submit your survey, please perform the following steps:

1. Save the completed word document using the File Save command.
2. E-mail the saved word document as an attachment to the following address: vlenss@mit.edu

Thank you for completing this survey.

Appendix V – Control Survey Pair-Wise Correlations

The following table lists the important interactions of variables for where a high degree of correlation was observed. The Communication situation, variables, and meaning of the interaction are listed in the table.

Type: Context of knowledge transfer (knowledge between all combinations of Tacit and Explicit)
E-T: explicit to tacit, **T-E**: tacit to explicit, **E-E**: explicit to explicit, T-T: tacit to tacit
F-F: face to face

#	Correlated Conditions				Meaning / Notes
	Variable 1		Variable 2		
	Type	Attribute	Type	Attribute	
1	E-T	Service	E-T	Organize	Attribute correlation matches the rotated factor analysis – contained in Factor 1
2	E-E		E-E		
3	T-T	Ease	T-E	Ease	Indicates "ease of use" was valued the similarly across different communication contexts – connected to the high value of "ease of use" across all communication needs
4	E-T		T-E		
5	E-E		T-E		
6	E-E		T-T		
7	E-E		E-T		
– the lack of correlation between E-T & T-T probably an indication of different needs between these 2 situations					
8	T-T	Person	T-E	Person	Indicates personalization was valued similarly across different communication contexts.
9	E-T		T-E		
10	E-E		T-E		
11	E-E		T-T		
12	E-E		E-T		
– the lack of correlation between E-T & T-T probably an indication of different needs between these 2 situations					
13	T-T	Feedback	T-E	Feedback	Feedback valued similarly in ½ of the communication contexts. Lack of E-E correlation is consistent with Factor Analysis.
14	E-T		T-E		
15	E-T		T-T		
16	T-T	Security	T-E	Security	Security valued similarly across different communication contexts.
17	E-T		T-E		
18	E-T		T-T		
19	E-E		T-E		
20	E-E		T-T		
21	E-E		E-T		
22	T-T	Organize	T-E	Organize	Organization valued similarly across different communications context with the exception of E-E, which is consistent with factor analysis.
23	E-T		T-E		
24	E-T		T-T		
25	T-T	Service	T-E	Service	Service correlated well across different communication needs.
26	E-T		T-E		
27	E-T		T-T		
28	E-E		T-E		
29	E-E		T-T		
30	E-E		E-T		

#	Correlated Conditions				Meaning / Notes
	Variable 1		Variable 2		
	Media	Attribute	Media	Attribute	
31	E-mail	Service	E-mail	Security	People view E-mail Service and Security similarly- may be that people infer one from the other
32	Video	Feedback	Video	Personalize	People view Feedback and Personalization attributes of Video similarly
33	Voice	Service	Voice	Feedback	People view Service and Feedback attributes of Voice similarly
34	F-F	Security	F-F	Feedback	People view Security and Feedback attributes of Face-Face communications cimilarly
35	Fax	Feedback	Fax	Personalize	connected to the inability to personalize or get feedback from Fax communications
36		Service		Ease	People consistently found fax communications reliable and easy to use giving the attributes a high correlation
37	F-F	Ease	Email	Ease	Easy of use was highly correlated and rated high for these communication media
38	Voice		Email		
39	Voice		F-F		
40	Voice	Personalize	F-F	Personalize	People had similar values of voice and face-face communications for personalization. This result is understandable as these two are closely related. This matches what had been expressed in our previous qualitative interviews where high value was placed on the ability to personalize messages in face-face or voice communications.
41	Fax	Feedback	Web	Feedback	These similar values of feedback for Fax and Web are probably and indication of the similar lack of feedback when communicating with these media.
42	F-F	Organize	Video	Organize	Indicates similar values for Organization for these communication media. This is related to the inability of these media to have organization capabilities.
43	Voice		Video		
44	Voice		F-F		

Appendix VI – Work Transformation Matrix Analysis Results

Email Language Scenario

Email-Language Work Transformation Matrix =

0	0.0608	0.0689	0.0648	0.0648	0.0638	0.0638
0.0608	**0**	0.0689	0.0648	0.0648	0.0638	0.0638
0.0721	0.0721	**0**	0.0615	0.0615	0.0608	0.0608
0.0648	0.0648	0.0684	**0**	0.0608	0.0623	0.0623
0.0648	0.0648	0.0684	0.0608	**0**	0.0623	0.0623
0.0664	0.0664	0.0653	0.0626	0.0626	**0**	0.0608
0.0664	0.0664	0.0653	0.0626	0.0626	0.0608	**0**

Email-Language Eigenvectors =

-0.3792	0.3809	-0.0357	-0.0500	-0.7071	0.1700	0.1902
-0.3792	0.3809	-0.0357	-0.0500	0.7071	-0.1700	-0.1902
-0.3809	-0.7553	0.5700	-0.4034	0.0000	-0.0000	-0.0000
-0.3763	0.1884	-0.5202	-0.3001	0.0044	0.5585	0.2472
-0.3763	0.1884	-0.5202	-0.3001	-0.0044	-0.5585	-0.2472
-0.3769	-0.1848	0.2562	0.5710	0.0031	0.3989	-0.6346
-0.3769	-0.1848	0.2562	0.5710	-0.0031	-0.3989	0.6346

Email-Language Eigenvalues =

0.3854	0	0	0	0	0	0
0	**-0.0736**	0	0	0	0	0
0	0	**-0.0666**	0	0	0	0
0	0	0	**-0.0628**	0	0	0
0	0	0	0	**-0.0608**	0	0
0	0	0	0	0	**-0.0608**	0
0	0	0	0	0	0	**-0.0608**

Email-Language Work Vector =

1.6294
1.6294
1.6323
1.6240
1.6240
1.6251
1.6251

Face-to-Face Language Scenario

Face-to-Face-Language Work Transformation Matrix =

0	0.0300	0.0382	0.0340	0.0340	0.0330	0.0330
0.0300	**0**	0.0382	0.0340	0.0340	0.0330	0.0330
0.0414	0.0414	**0**	0.0307	0.0307	0.0300	0.0300
0.0340	0.0340	0.0377	**0**	0.0300	0.0315	0.0315
0.0340	0.0340	0.0377	0.0300	**0**	0.0315	0.0315
0.0357	0.0357	0.0345	0.0318	0.0318	**0**	0.0300
0.0357	0.0357	0.0345	0.0318	0.0318	0.0300	**0**

Face-to-Face-Language Eigenvectors =

-0.3803	0.3819	-0.0373	0.7071	-0.0454	-0.0311	-0.0314
-0.3803	0.3819	-0.0373	-0.7071	-0.0454	0.0311	0.0314
-0.3837	-0.7500	0.5602	-0.0000	-0.3892	0.0000	0.0000
-0.3747	0.1938	-0.5260	0.0000	-0.2996	0.4995	0.5853
-0.3747	0.1938	-0.5260	0.0000	-0.2996	-0.4995	-0.5853
-0.3760	-0.1880	0.2550	0.0000	0.5766	0.4995	0.3955
-0.3760	-0.1880	0.2550	0.0000	0.5766	-0.4995	-0.3955

Face-to-Face-Language Eigenvalues =

0.2008	0	0	0	0	0	0
0	**-0.0430**	0	0	0	0	0
0	0	**-0.0359**	0	0	0	0
0	0	0	**-0.0300**	0	0	0
0	0	0	0	**-0.0320**	0	0
0	0	0	0	0	**-0.0300**	0
0	0	0	0	0	0	**-0.0300**

Face-to-Face-Language Work Vector =

1.2529
1.2529
1.2554
1.2487
1.2487
1.2497
1.2497

Voice Language Scenario

Voice-Language Work Transformation Matrix =

0	0.0631	0.0724	0.0677	0.0677	0.0665	0.0665
0.0631	**0**	0.0724	0.0677	0.0677	0.0665	0.0665
0.0761	0.0761	**0**	0.0640	0.0640	0.0631	0.0631
0.0677	0.0677	0.0718	**0**	0.0631	0.0648	0.0648
0.0677	0.0677	0.0718	0.0631	**0**	0.0648	0.0648
0.0696	0.0696	0.0683	0.0651	0.0651	**0**	0.0631
0.0696	0.0696	0.0683	0.0651	0.0651	0.0631	**0**

Voice-Language Eigenvector =

0.3793	0.3809	-0.0364	0.7071	-0.0513	0.0302	0
0.3793	0.3809	-0.0364	-0.7071	-0.0513	-0.0302	0
0.3814	-0.7567	0.5964	-0.0000	-0.4129	-0.0000	0
0.3761	0.1876	-0.5149	0.0000	-0.2921	-0.4995	0
0.3761	0.1876	-0.5149	0.0000	-0.2921	0.4995	0
0.3768	-0.1828	0.2360	-0.0000	0.5717	-0.4995	0.7071
0.3768	-0.1828	0.2360	-0.0000	0.5717	0.4995	-0.7071

Voice-Language Eigenvalues =

0.4023	0	0	0	0	0	0
0	**-0.0779**	0	0	0	0	0
0	0	**-0.0699**	0	0	0	0
0	0	0	**-0.0631**	0	0	0
0	0	0	0	**-0.0653**	0	0
0	0	0	0	0	**-0.0631**	0
0	0	0	0	0	0	**-0.0631**

Voice-Language Work Vector =

1.6756
1.6756
1.6795
1.6693
1.6693
1.6707
1.6707

Email Culture Scenario

Email-Culture Work Transformation Matrix =

0	0.0608	0.0831	0.0766	0.0766	0.0724	0.0724
0.0608	**0**	0.0831	0.0766	0.0766	0.0724	0.0724
0.0998	0.0998	**0**	0.0766	0.0766	0.0646	0.0646
0.0948	0.0948	0.0787	**0**	0.0608	0.0704	0.0704
0.0948	0.0948	0.0787	0.0608	**0**	0.0704	0.0704
0.0931	0.0931	0.0787	0.0729	0.0729	**0**	0.0608
0.0931	0.0931	0.0787	0.0729	0.0729	0.0608	**0**

Email-Culture Eigenvectors =

0.3635	0.5621	-0.0032	0.0026	0.7071	0.5221	-0.0080
0.3635	0.5621	-0.0032	0.0026	-0.7071	-0.5221	0.0080
0.3896	-0.3755	-0.8510	-0.7553	0.0000	0.0000	-0.0000
0.3815	-0.2760	0.1391	0.4601	-0.0015	0.4749	-0.2329
0.3815	-0.2760	0.1391	0.4601	0.0015	-0.4749	0.2329
0.3827	-0.1931	0.3443	-0.0559	0.0001	-0.0432	-0.6676
0.3827	-0.1931	0.3443	-0.0559	-0.0001	0.0432	0.6676

Email-Culture Eigenvalues =

0.4631	0	0	0	0	0	0
0	**-0.1197**	0	0	0	0	0
0	0	**-0.0766**	0	0	0	0
0	0	0	**-0.0844**	0	0	0
0	0	0	0	**-0.0608**	0	0
0	0	0	0	0	**-0.0608**	0
0	0	0	0	0	0	**-0.0608**

Email-Culture Work Vector =

1.8273
1.8273
1.8942
1.8737
1.8737
1.8766
1.8766

Face-to-Face Culture Scenario

Face-to-Face-Culture Work Transformation Matrix =

0	0.0300	0.0463	0.0417	0.0417	0.0387	0.0387
0.0300	**0**	0.0463	0.0417	0.0417	0.0387	0.0387
0.0578	0.0578	**0**	0.0417	0.0417	0.0328	0.0328
0.0544	0.0544	0.0432	**0**	0.0300	0.0372	0.0372
0.0544	0.0544	0.0432	0.0300	**0**	0.0372	0.0372
0.0533	0.0533	0.0432	0.0390	0.0390	**0**	0.0300
0.0533	0.0533	0.0432	0.0390	0.0390	0.0300	**0**

Face-to-Face-Culture Eigenvectors =

0.3599	0.5548	0.0037	0.0067	0.7070	0.0167	-0.0000
0.3599	0.5548	0.0037	0.0067	-0.7070	-0.0167	0.0000
0.3922	-0.3753	-0.8481	-0.7494	0.0000	-0.0000	0.0000
0.3821	-0.2836	0.1485	0.4644	-0.0122	0.7069	0.0000
0.3821	-0.2836	0.1485	0.4644	0.0122	-0.7069	-0.0000
0.3841	-0.2033	0.3439	-0.0589	0.0000	0.0000	-0.7071
0.3841	-0.2033	0.3439	-0.0589	0.0000	0.0000	0.7071

Face-to-Face-Culture Eigenvalues =

0.2516	0	0	0	0	0	0
0	**-0.0723**	0	0	0	0	0
0	0	**-0.0417**	0	0	0	0
0	0	0	**-0.0476**	0	0	0
0	0	0	0	**-0.0300**	0	0
0	0	0	0	0	**-0.0300**	0
0	0	0	0	0	0	**-0.0300**

Face-to-Face-Culture Work Vector =

1.3181
1.3181
1.3525
1.3421
1.3421
1.3439
1.3439

Voice Culture Scenario

Voice-Culture Work Transformation Matrix =

0	0.0631	0.0834	0.0775	0.0775	0.0738	0.0738
0.0631	**0**	0.0834	0.0775	0.0775	0.0738	0.0738
0.0985	0.0985	**0**	0.0775	0.0775	0.0666	0.0666
0.0940	0.0940	0.0795	**0**	0.0631	0.0719	0.0719
0.0940	0.0940	0.0795	0.0631	**0**	0.0719	0.0719
0.0925	0.0925	0.0795	0.0742	0.0742	**0**	0.0631
0.0925	0.0925	0.0795	0.0742	0.0742	0.0631	**0**

Voice-Culture Eigenvector =

0.3649	0.5651	-0.0015	0.0030	0.7071	-0.0331	-0.1066
0.3649	0.5651	-0.0015	0.0030	-0.7071	0.0331	0.1066
0.3883	-0.3730	-0.8548	-0.7542	0.0000	0.0000	-0.0000
0.3811	-0.2730	0.1373	0.4604	0.0028	0.7054	-0.2797
0.3811	-0.2730	0.1373	0.4604	-0.0028	-0.7054	0.2797
0.3823	-0.1911	0.3403	-0.0604	0.0001	0.0371	-0.6406
0.3823	-0.1911	0.3403	-0.0604	-0.0001	-0.0371	0.6406

Voice-Culture Eigenvalues =

0.4684	0	0	0	0	0	0
0	**-0.1168**	0	0	0	0	0
0	0	**-0.0776**	0	0	0	0
0	0	0	**-0.0847**	0	0	0
0	0	0	0	**-0.0631**	0	0
0	0	0	0	0	**-0.0631**	0
0	0	0	0	0	0	**-0.0631**

Voice-Culture Work Vector =

1.8485
1.8485
1.9095
1.8910
1.8910
1.8939
1.8939