# Asynchronous Videoconferencing: A Hybrid Communication Prototype

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## Abstract

*This report introduces a hybrid asynchronous, distributed audio/video group conferencing system. One of the chief benefits of Internet communication systems is that they allow communicators to write messages when they need to, and read messages when they can. Researchers, developers, and lay citizens are increasingly familiar with one of the benefits of e-mail and online text conferencing systems: the ability to use asynchronous, store-and-forward and retrieve-on-demand technologies for communication. However, most theories of interactive technologies suggest that users would achieve more accurate interpersonal perceptions and more effective and efficient work transactions if all visual and auditory non-verbal cues were available via desktop communication systems. Synchronous multimedia communication technologies achieve this, but forego the benefits of store-and-forward and retrieve-on-demand. The technological barrier has been in wedding asynchronous communication to the storage, indexing, and retrieval of sound and video.*

*This paper reviews the literature on the costs and benefits of synchronous and asynchronous interaction, and full- versus partial-cue messaging that prompted development of the system. It also discusses the technological basis of a working prototype asynchronous audio/video conferencing system, including its facility for a non-linear indexing system that allows users to access a/v messages by order, topic, time, or participant subset. Validation tests for the utility of asynchronous a/v that are being conducted are discussed. These address the affective, co-presence, satisfaction, and effectiveness outcomes such a system provides.*

## 1. Introduction

As digitally-based communication technologies have developed over the last several decades, users, designers, and analysts have contended with and considered the trade-offs between two primary communication attributes: multi-channel, multi-cue communication versus asynchronous, store-and-forward, indexed conversation threads. As the technologies continue to develop, the question of which medium to select for a particular interaction has become more complex and more important. Further, the design of the interface in terms of which features ought to be included for what type of interaction has become an increasingly important decision for designers of systems. "We can think of the interface as the part of the system that 'faces' the interactant, especially when that interactant is a human operator. The interface is quite literally the 'face' of the telecommunication system, the only part of the weave of copper, silicon, and plastics that the user sees, hears, and touches" [1]. Traditional face-to-face communication, and its close cousin videoconferencing, which offers synchronous audio and visual information offers advantages in comprehension and mutuality that no asynchronous communication system has yet to match. On the other hand, asynchronous communication offers convenience, storage and retrieval for review, and ways to focus and re-arrange message segments across time zones and distributed locations that have revolutionized distributed work. Further, these asynchronous systems take better advantage of the packet switching protocols of the Internet. Unfortunately, while these two attributes—full cues and asynchronous messaging—are not in principle exclusive to one another, technological development has, up until the present, been unable to merge them. This report describes the development of new technology that attempts to redress this missing nexus. In the following pages, we describe the rationale, technical specifics, and initial tests of an indexable, asynchronous videoconferencing system that will allow groups to share communication across time and space using verbal, vocal, and visual cues.

### 1.1. Benefits of asynchronous communication

With the diffusion of the ARPANet and Internet, scientists and citizens have adopted electronic mail at exponential rates. One of e-mail's chief attractions leading to its adoption is its affordance of the ability to send messages to others when one wishes, with little time lag for those messages to be available, yet for the recipients, to be able to access those messages at their own discretion. Obviously superior to postal mail or courier in terms of delivery time, the store-and-forward capacity of asynchronous communication facilitates the ability to disperse partnerships across space (since people need not be physically co-located in order to communicate) and across time (since people need not attend to communication simultaneously; see [34]. This characteristic not only allows members to attend to information at times at which they can turn their attention to group problems, but liberates message senders from having to wait until group members can be gathered or summoned telephonically, preventing "production blocking" (the tendency to hold back or forget information while waiting for a live speaking turn; see [3]) from occurring. These are limitations of asynchronous interactions which must be contrasted with potential loss of the sense of a connection with another in real time. This project will test the extent of this potential loss.

Clearly this capability has contributed to the ability of groups and organizations to disperse their members geographically, even across multiple time zones [14]. In terms of the quality of group interaction, asynchronous communication channels allows groups to re-entrain themselves, that is, to overcome the problems associated with competing demands for attention and time, that face-to-face meetings often portend, by writing and responding conveniently [10], [40].

Concurrent with these benefits are certain "second-level" attributes (i.e. social phenomena enabled by the technology aside from it was designed to do). For instance, communicators are able to consider their messages carefully as they compose them since they are not bound by the time pressure that the norms of face-to-face encounters demand [11]. Moreover, when Usenet-like systems or deliberately designed group conferencing or bulleting board systems are employed, individuals who join a group after its beginnings can review previous comments and catch up to the rest of the group [34]. Further, Usenet and asynchronous computer conferencing structure and arrange the connectedness and display of messages according to several schemes, which may include by-person, by date, and/or by topic. Such indexing allows users to focus their messaging and their message retrieval activities according to orders and characteristics more related to the reader's importance simply taking all comments chronologically and equally [27].

While numerous benefits deriving from asynchronous electronic interaction are posited, some concerns have been raised about asynchrony's disruption of communication. McGrath [21], particularly, challenges text-based electronic communication's ability to foster conversational coherence, i.e. the ability of users to make sense of conversation that would normally be interpretable through adjacency of utterances and recursive references; this seems especially unlikely in asynchronous messaging, according to McGrath. However, these concerns seem to ignore others' speculations and later findings about users' abilities to achieve interactivity despite time lags (c.f. [25], [26]) and system designers' efforts to replace conversational characteristics with pointers and quoting devices; by indexing message threads and referencing messages to one another, users are able to make sense of context and continuity of discussions regardless of their dispersion over time [36], [37]. The question here becomes whether or not technology can provide features to facilitate interpersonal or task based interactions that would overcome any limitations resulting from the asynchronous nature of the interaction.

### 1.2. Benefits of multiple cues

Despite these advantages of asynchronous interaction, most asynchronous systems have involved text-based messaging only, demanding that users expend extra effort in order to achieve common understanding and develop perceptions of partners without the nonverbal communication and physical appearance cues that face-to-face communication provides. Several theories have suggested that communication systems with diminished nonverbal cues may be inadequate for complex and/or interpersonally-involving tasks, most notably social presence theory [32], the social context cues hypothesis [33] and media richness theory [4]. These theories argue that expedient comprehension or interpretive social contexts depend on the transmission of multiple communication cues. These theories have recently been shown to be limited in their predictive validity as far as users capabilities for performance and interpersonal relations are concerned (c.f. [5], [31], [44]). Nevertheless, there is robust evidence that users prefer multimedia/full cue communication despite its questionable necessity (e.g. [7], [30], 35]). Why might this be the case?

One approach to users' preference for full-channel communication takes a communication efficiency framework [42]. While limited-bandwidth communication may theoretically perform all functions

that face-to-face interaction provides, full-channel communication does so with less cognitive and behavioral effort, in less time, than text-based systems. Previous theorizing about the relationship of verbal and nonverbal cue systems suggests that human multi-channel communication allows for complementary simultaneous signals to be processed [2]. That is, human evolution has yielded our capability to transmit substantive and affective information simultaneously through the complementary channels of verbal and nonverbal communication, with little conscious effort, as we have done in face-to-face interactions.

This would not be the case if nonverbal communication was redundant to verbally-transmitted information. But the relationship of nonverbal to verbal behavior is often complementary, rather than redundant, with nonverbal behavior adding qualification, uncertainty, or contradiction to the verbal substance [6]. When verbal and nonverbal indicators contradict one another, people have been shown to prioritize the nonverbal [2]. Processing both messages is possible in a unitary-symbol system such as text-based communication, but in that mode the transmission of complementary levels of information must be accomplished by conscious and relatively greater efforts to translate these multiple signals into the semiotics of the unitary channel [38]. Thus, full-channel communication represents a less effortful and more highly efficient system for the conveyance of complex information, such as a topic involving both substantive and affective/attitudinal issues. When a topic's complexity is great, it may require additional cognitive demands for deliberation. Further, if communication involving multiple simultaneous cues is less effortful, it should allow partners to reserve more effort to their information processing task and less to their intentional communication behavior. While this perspective may seem to present an overly-complex rationale for the advantage of face-to-face and video-based communication, it is relatively unique in its recognition of single-cue systems' capacity to afford complex information processing compared to multi-cue systems' greater efficiency and less effort to do so (c.f. [17]). From a cognitive perspective, the implication that the expenditure of less communicative effort frees partners' cognitive resources for substantive information processing predicts greater satisfaction and more successful deliberative outcomes [24].

In addition to the intersubjective information processing efficiency advantages that multi-cue communication provides, video-based communication provides potential advantages that non-visual communication cannot, even if ideas are effortfully translated into language. As Whittaker [45], [46] has argued, the functions of visual information in communication episodes transcend information emanating from the communication partners themselves. Video provides a shared workspace, allowing communicators to sense environmental cues that contextualize and therefor add meaning to the references they bring up through speech and action. Video furthermore allows for the observation of specific artifacts, which may be the target of discussion and deliberation. This may further contextualize discussion, or allow users to adapt their language to even more efficient referential, rather than descriptive, speech (i.e. referring to an object all can see as "that" or by mentioning its attribute, rather than repetitively describing what it is in order to focus attention [8]. In many cases video may be more useful than even unmediated face-to-face communication. For example, when a discussion is focused on a "common virtual object" rather than on the users themselves [8]. Videoconferencing thus provides particular communicative advantages to geographically and/or temporally dispersed groups that text-based communication cannot, at least under some circumstances.

At the same time as a good case can be made for the benefits of multi-modal, full-channel communication, empirical research has yielded mixed results from the use of synchronous, or real-time videoconferencing. For example, While Mühlfelder, Klein, Simon, and Luczak [22] found no differences in interpersonal trust between videoconferencing and face-to-face communication, Hinds [12] found that real-time videoconferencing overloaded the cognitive processing of team partners performing a complex task, and biased their perceptions of one another, compared to those groups using a text-based conferencing system. Matarazzo and Sellen [19] similarly found that a low-grade, synchronous video system provided better support than a high-grade videoconferencing parallel; subjects rated the poor quality video system more favorably than comparable high quality system, and they completed their tasks more quickly using the inferior system, effects which the researchers attribute to the distraction factor that full-quality video provided in distracting from the task at hand. While these effects question the utility of synchronous videoconferencing, the pressure to process all information—relevant and distracting—that real-time interaction demands, may be ameliorated if interactions are spread out over time using asynchronous messaging.

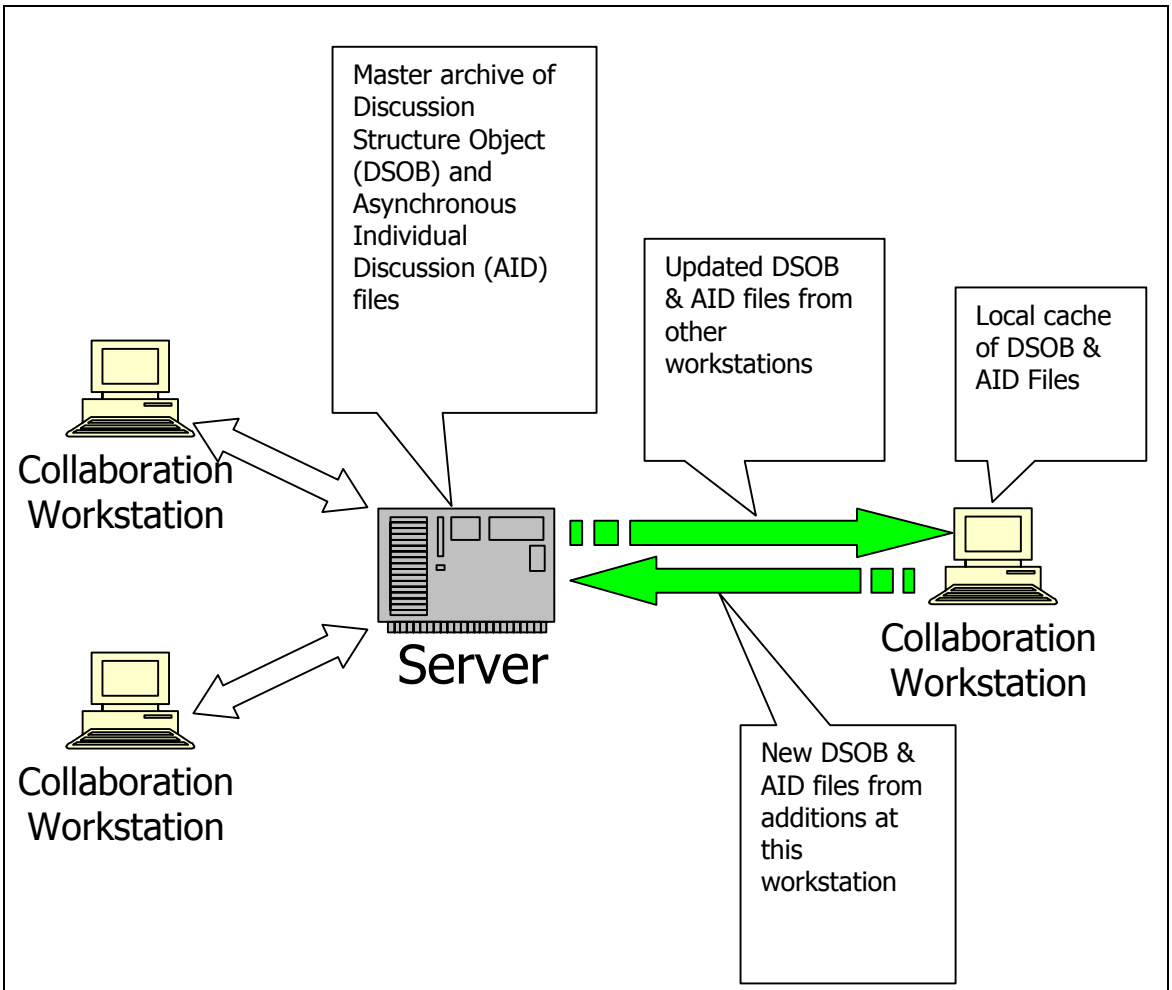


**Figure 1. Schematic Operation of TIC System**

## 2. Asynchronous videoconferencing

Based on the above rationale, it appears that both videoconferencing and asynchronous communication sometimes offer features that may benefit virtual groups' coordination and comprehension, and in so doing, their effectiveness and satisfaction with the interaction as well as their interaction partners. Melding the common attributes of asynchronous conferencing systems and full-channel audio/video communication should provide advantages greater than either set alone. Yet this combination of attributes has been overly formidable to accomplish in the past. "Video-mail" has recently seen some experimentation (c.f. [13]), and is even becoming widely available with inexpensive desktop cameras and software that creates audio/video captures and appends them to e-mail. But this technology has been applied only in point-to-point systems. Missing elements that would truly offer a hybrid of video with the attributes of text-based group conferencing would require additional features. These include central maintenance of video clips in a server/client storage and delivery system, indexing and cross-listing of video-recorded content, and flexible dynamic organization of video clips in some kind of user-adjustable grouping or indexing system for playback by temporal, topical, or author-based retrieval requests. In the following, we present a description of such a system, which now exists as a working prototype.

### 2.1. Development of the Time Independent Collaboration (TIC) system

**2.1.1. Technical operation.** The TIC system is a client-file server system. Individuals at collaboration workstations record discussion comments into audio/visual files called Asynchronous Individual

Discussion (AID) files. The server maintains a master archive of these files and of their logical relationships in the context of the collaborative discussion. The logical relationships of AID files are defined in Discussion Structure Object (DSOB) files. Collaboration workstations maintain a local cache of AID files and DSOB files, and discussants at the workstations play back and record comments using a very simple client interface. Figure 1 shows a schematic representation of the system.

**2.2.2. Sequence of Operations.** A new discussion is activated by a TIC moderator who has administrative privileges for the TIC system. Moderators, in turn, are designated by the TIC System Administrator, who has full responsibility for the system. Moderators have access to the TIC server from anywhere on the Internet via a TIC moderator's client application. Moderators can add discussants and assign them user names and passwords, which they will use to access the discussions, remove discussants, edit the discussion, and carry out other activities to monitor and facilitate the collaboration. The moderator records an opening message that activates the discussion.

Once the discussion is activated, discussants log on at any time from TIC collaboration workstations. Collaboration workstations are simple Windows-based computers with a Web camera, microphone and TIC client software installed.

When the TIC client software at a workstation is activated, it contacts the TIC server. The server then interacts with the client to determine two things: (1) has the client recorded new AID files off-line since the last time the discussant logged on; and (2) does the client have the most current DSOB and AID files. Any new discussant AID files are uploaded by the server and added to the master archive, then the client downloads the fully updated DSOB and AID files from other discussants that have accumulated since the discussant's last logon. After this process, the client workstation has a fully updated copy of the most current version of the discussion ready for playback.

The discussant can then play back the discussion in a number of flexible ways:

1. The full discussion in chronological order.
2. New discussion since the last log on.
3. Discussion items specified from the combination of any or all of a number of attributes:
   a. Between two specified time points.
   b. By a specified subset of individuals chosen from all the discussion participants.
   c. By topic.
4. Single discussant's comments chosen from a visual representation of the discussion.

**2.1.3. File contents.** The Discussion Structure Object File contains a tree structure that links individual AID files both chronologically and by topic. It serves as an index to the full discussion, and contains information about each individual AID file created by a discussant. This information includes the discussant's identification, the time of creation of the AID file, and a topic line that is entered by the discussant when recording a comment to add to the discussion. The local DSOB is sent from the client to the server when the client logs on, and the server uses it to determine what files need to be transferred in order to update both the server archive and the client's cached copy. After updating, the server DSOB and the client's DSOB are identical.

In the prototype system, the AID files are currently Windows Media (.AVI) files, although these are somewhat larger than alternative file formats. Each AID file is uniquely named by the client software, so that each video clip of a discussant's comments retains its unique name on both the server archive and in all client caches.

### 2.2 Further development of TIC

The feasibility of automatic topic indexing from the audio track of AID files is being investigated. Voice-recognition software is used to produce a text file transcript of each AID file, and semantic extraction procedures are then used to produce a set of topic keywords. These are added to the DSOB topic fields, so that users can playback the discussion by topic. The extracted topics will be displayed by the TIC interface as a kind of index to the discussion, as well.

## 3.0. Projected evaluations and experimentation

The first round of evaluation research will beta-test the TIC system and pre-test the measures that will be used in subsequent experimental tests. Participants will be assigned to groups who will use the TIC system for the development of group research projects for an undergraduate communication course at a northeastern university on the US. Evaluations will include the assessment of system failure reports, and interviews with participants to find out what features were difficult to learn and use.

Formal testing of the effectiveness of the system will commence once the beta tests and revisions to the system have been completed. Drawing on previous research in the areas of computer-mediated communication in groups, and mindful of the various alternatives—both synchronous and asynchronous--to which the TIC system might logically be compared,

groups will conduct the same variations of tasks using the TIC system, using face-to-face meetings, asynchronous text-based computer-mediated groups, or using real-time videoconferencing. Outcome measures will assess their experiential responses to the system, the subjective satisfaction of the participants, their socioemotional responses, and their task effectiveness—variables that have become the standard criteria for group work in mediated and unmediated settings. Research will explore the following research questions:

- Does asynchronous videoconferencing achieve greater social presence, copresence, satisfaction, and performance, than face-to-face communication, synchronous videoconferencing, or text-only asynchronous conferencing?
- Does asynchronous videoconferencing achieve the above effects differently on "self-referential" versus "object-referential" discussions (i.e. discussions focused on individuals' opinions, attitudes, and preferences versus discussions focused on commonly developing objects or artifacts)?

### 3.1. Methods

One hundred and twenty students will be recruited in exchange for extra credit in one of several communication and psychology courses at two different universities in the northeastern US. Participants will be assigned to groups consisting of three members using randomized-blocked design so that there will be a near-equal number of face-to-face groups at each university, and an equivalent number of distributed groups in each of the other conditions. The overall design will be 4 by 2 experimental arrangement, with 5 groups (15 individuals) within each of the 8 conditions. There are 4 levels of communication condition: TIC (asynchronous audio-video), face-to-face, synchronous distributed video, and asynchronous computer conferencing. These conditions are crossed by two levels of task: a decision-making task involving values and preferences (the self-referential task), and a task that references an object--a document design task, in which groups must decide how to order and arrange the home page for a research laboratory given a loose set of requirements and some content elements. All group members will be told that they have been recruited to complete three, rather than one, task. Although only one task will be required from them in actuality, previous research on computer-mediated groups establishes that the anticipation of future interaction can interact with, and override the effects due to differences between media and face-to-face settings [39], [41], an effect that should be made constant in the present research so that other between-media differences can be detected.

Face-to-face groups will meet in communication research laboratory rooms at the respective universities. Synchronous videoconferencing will be achieved by having group members report to separate rooms in the communication research laboratories at each university, where desktop computers, microphones, and cameras will be stationed, and connected to a CUSeeMe server system to provide real-time audio/video connectivity between the rooms and across universities. Face-to-face and real-time videoconferencing groups will be scheduled so that they have up to an hour to complete their tasks, although it is expected that the tasks will take substantially less time to complete. The relatively long time period will ameliorate the impact that time pressure might otherwise exert on participants in face-to-face or mediated interaction strategies (see [16], [28], [29]).

Asynchronous text-based conferencing groups' members will use the bulletin board, or Forum utility, in WebCT. WebCT is a web-based courseware system that is in use at these universities, with which students are familiar, and each student will have access to special forums established for purposes of this research. While previous familiarity may present a minor confound, compared to other more novel systems in this research, no training will be necessary. Training on an alternative conferencing system would require either numerous one-on-one sessions, or group sessions that would present face-to-face encounters among otherwise virtual partners.

Asynchronous audio-video teams will employ the TIC system described in this report. Asynchronous text groups and asynchronous a/v groups will be given two weeks to complete their task (see for equivalency Walther & Burgoon [43]).

At the completion of the tasks, participants will complete self-administered questionnaires presented to them via World Wide Web pages embedded with data-gathering forms.

### 3.2. Measures

**3.2.1. Partner satisfaction**. Partner satisfaction will be a Likert-type scale consisting of ten indicators from McCroskey's [20] credibility measures, including whether the partners were professional, cooperative and knowledgeable.

**3.2.2 Presence**. Presence is a measure of the feeling a person has s/he is "inside" a virtual environment. This measure was developed byLombard and Ditton [18] in order to measure psychological immersion. Eight 7-interval Likert-type items form the scale, which

includes indicators such as how intense the experience in the environment is and the extent to which the experience is involving and immersive.

**3.2.3. Copresence**. Copresence is related to the feeling of connection between two people, that is, the sense that one is actively being perceived and that one is actively perceiving another [9], [23]. Given its bidirectional nature, this is measured by two separate scales, one asking about the participant's perception of his/her partner's involvement in the interaction, and the other asking the participant about his/her own involvement in the interaction.

The scale measuring the perceived copresence of the interaction partner includes 15 indicators taken from three of the dimensions of immediacy: immediacy/affection, similarity/depth, and receptivity/trust. Items are derived from relational communication measures revised for groups in computer-mediated communication by Walther and Burgoon [43]. These measures have been used in several experiments comparing mediated and unmediated communication, and assess the extent to which partners appear to be involved, interested, and/or emotional in the conversations. It also measures the extent to which the interaction partners made the conversation seem superficial or created a sense of distance between them.

The second scale will include 11 indicators similar to those above, but revised to ask how involved the participant was in the interaction. These items will measure the extent to which the participant self-reported being copresent in the interaction and whether s/he was interested in a deeper relationship or more intimate conversation with interaction partners.

**3.2.4. Social presence**. Social presence, or the perceived ability of the medium to connect people (ability of the medium itself to provide social presence), will consist of 9 slightly modified items from Short, Williams and Christie [32]. The scale will include questions about how the person at the other end seemed, whether or not the medium provided a sense of realism, and whether or not one could get to know a person s/he encountered only through the medium in question.

**3.2.5. Performance**. Performance will be measured several ways. *Quality* of the groups' final decisions and designs will be rated by graduate students in communication and information technology, respectively, with expertise in these processes, yet blind to experimental treatments. *Efficiency* will be calculated by calculating a coefficient of quality divided by the elapsed time that groups used for communication (with asynchronous/text groups' time determined from the system records of the WebCT server).

## 4. Conclusion

The convenience and appeal of asynchronous communication, instantly conveyed and indefinitely stored, has transformed social life and professional practices in ways that few would have imagined not too many years ago as email and conferencing systems have pervaded society and business. The benefits of such systems hardly need repeating, and despite the comparatively tedious interface that text-based CMC requires, asynchronous messaging has become a staple. Yet in spite of the wide diffusion and now-commonplace nature of text-based systems, and the evidence from empirical research questioning its value, users' articulated preference for the best and easiest communication interface for moderately complex tasks consistently falls on full-cue communication: face-to-face, or really good videoconferencing. Until now, one had to choose between the convenience of asynchronous messaging or full bandwidth. Or, using videoconferencing, partners incurred potential losses due to the distracting effects required by the management of both central and peripheral information that real-time systems demand. The TIC system described in this report makes these choices and trade-offs moot, providing as it does sound and video, in a recorded, storage-and-retrieval system, indexed to facilitate examination and comprehension by distributed group members.

What new choices will confront users and researchers with the success of the TIC system? Clearly, new questions, barely imaginable now, will be able to be asked and answered. For example, for what purposes, or for what people, is full bandwidth asynchronous interaction advantageous or disadvantageous? Do individuals have media preferences, not just in terms of consumption, but production as well? As text-based conferencing was promised to "level the playing field" for people with different appearances, will convenient videoconferencing-on-demand level the playing field for those whose oral descriptions and gestures are more compelling than the prose, spelling, and written grammar with which they are otherwise able to express them? Will asynchronicity allow message receivers to examine and re-examine the underlying substance of a partner's arguments, rather than be swayed or distracted by the video-conveyed charisma that full-channel communication can impel in a real-time encounter? Numerous questions--theoretical, practical, and philosophical--arise when communication breaks further through linear time and space, as asynchronous video communication has the potential to provide.

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