Thunderwire: A Field Study of an Audio-Only Media Space

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ABSTRACT

To explore the potential of using audio by itself in a shared media system, we studied a workgroup using an audio-only media space. This media space, called Thunderwire, combined high-quality audio with open connections to create a shared space for its users.

The two-month field study provided a richly nuanced understanding of this audio space's social use. The system afforded rich sociable interactions. Indeed, within the field study, audio by itself afforded a telepresent environment for its users. However while a usable media space and a useful social space, Thunderwire required its users to adapt to many audio-only conditions.

Keywords: Audio, audio spaces, media spaces, electronic social spaces, social presence, speech interactions, mediated communication, computer-mediated communication, CMC, telepresence, social interactions, rich interactions, norms

INTRODUCTION

Media spaces have existed in increasingly usable and powerful forms for over a decade [2]. As Meyrowitz explains, media have an extraordinary potential for creating new types of social spaces:

> ...The introduction and widespread use of a new medium of communication may restructure a broad range of situations and require new sets of social performances. ([18], p. 39)

Each type of media and by extension, each type of media space system, may allow people to interact in ways quite different from those occurring in face-to-face situations, through other media, or even in other types of media spaces.

In this study, we were interested in the potential of using only audio in a media space. Almost all media spaces have used video and audio together; however, relatively little is known about the relationship between the media mix and the development of a useful and usable social space [21]. Audio by itself, if usable, would be attractive because of its lower complexity and cost. As well, audio is an intriguing medium for collaboration and interaction (as shown in, e.g., [12, 24, 29]).

If audio by itself were indeed found to be usable and useful, it would also be important to characterize the space it created. We were especially interested in whether participants would have a sense of telepresence [3], or shared social presence. Accordingly, we examined a workgroup using an audio-only media space over several months. This media space system, called Thunderwire, combined high-quality audio with open connections to create a shared space for its users.

Our field study provided a richly nuanced understanding of the social uses of this audio space. We found that Thunderwire afforded a usable social space, but that the users were forced to adapt to many audio-only conditions. This paper presents the results of that field study.

The first section of this paper surveys the literature supporting the design of an audio-only system. The next section describes the important characteristics of the Thunderwire system, followed by a description of the field study, data, and study group. The majority of the paper analyzes Thunderwire's social use and characteristics. The first part of this analysis examines the interactions that were possible in this audio-only space, and the second part of the analysis examines the norms that the participants formulated to govern their use of the system. The final

section of the paper discusses the design and research implications. A transcript of a representative conversation, used throughout the paper, appears in Appendix A.

AUDIO MEDIA SPACES

The central question in this study was whether audio by itself might be suitable for media system use and if so, what type of space it would create. The potential of an audio-only media space intrigued us for a number of design, theoretical, and empirical reasons. As mentioned, from a design viewpoint, an audio-only system is considerably less complex, and therefore more practical, than one including video. Despite the design possibilities, to our knowledge there have been few field studies of audio-only media spaces, and no field studies of systems with good-quality audio. The remainder of this section, then, outlines the principal empirical and theoretical findings that led us to believe that such a study would be informative.

Audio-only in a media space

Substantial empirical support exists for believing that audio alone would be sufficient for a usable media system. There have been a great many studies comparing audio with video and with face-to-face interactions. We will be able to only briefly survey the major arguments here; for more detail, Sellen [25] provides a comprehensive summary.

In general, empirical findings in the literature have either pointed to the primacy of audio in communication, or at worse, the results have been mixed. From Chapanis' [4] comparison of media onward, audio has been found to have a primary role in communication. (See [22] for a summary.) In Chapanis' work, for example, task completion was found to be primarily dependent on having an audio channel; the inclusion of video was significant in only tasks requiring negotiation.

These results have been confirmed in recent studies of computer-mediated communication. For example, Sellen's experiments examined such conversational mechanisms as number of turns, turn duration, turn distribution, percentage of simultaneous speech, conversational switches, and types of simultaneous speech under face-to-face, video, and audio-only conditions. She found audio was not noteably different than video in terms of its communicative support; the real difference was whether there was any mediating technology. Sellen, however, also noted that only ten percent of her subjects preferred the audio-only condition.

More mixed results were reported by Olson et al. [21] who studied face-to-face, video, and high-quality audio conditions for distributed meetings. Their findings suggest that the quality of the task was lower in the audio-only condition than in face-to-face. Again, users preferred the video condition over audio-only. The authors suggested that users were responding to hidden process requirements. The latter suggestion was also made by Isaacs and Tang [14]. In summary, all of these studies report similar results: Users prefer video, but audio in general performs either as effectively or almost as effectively as face-to-face communication or video. Audio, if not ideal, should at least be suitable for a shared media system.

Specific design considerations

Specific characteristics of Thunderwire's design were informed by several additional studies. The various office-share studies (e.g., [6]) found continuous open audio to be important to creating and maintaining long-term interaction patterns, and bolstered our belief that a system with these features could create a viable social space. Gaver [10], pointed out the importance of ambient audio in the workplace. Similarly, Whittaker et al. [28] concluded from their study of informal workplace communication that persistent audio and video links would support frequent, brief interactions at minimal cost. They characterized workplace interactions as one long intermittent conversation.

Other studies that examined the audio-only condition in media spaces with multiple media (e.g., [9, 20, 21]) argued for providing good-quality full-duplex audio without any transmission lag. For example, Gale [9] found that high-quality audio resulted in faster group task completion times than did audio and video. There is also evidence that low-quality audio could adversely affect communication. O'Conaill et al. [20] looked at remote workgroups using videoconferencing over both ISDN (the low-quality condition) and broadcast (high-quality) networks, and compared them with the face-to-face condition. They concluded that low-quality, half-duplex audio with discernible lag causes more formality and conversational awkwardness. These results are similar to those found for telephone use (e.g., [23], [13]).

In summary, a number of studies suggested that audio, especially good-quality audio, would have a sufficient communicative capability for an interesting and useful shared media system. Such a system is described in the following section.

THE THUNDERWIRE SYSTEM

Thunderwire was an audio-only communication system conceptually similar to a telephone party line or conference call. The system was built by Interval to facilitate communication within a small group spread throughout two buildings. Thunderwire permitted any number of group members to be simultaneously connected, and anything said at any time by any member was heard by all.

The following were the important system characteristics of Thunderwire. They are critical for understanding the field study results:

- Thunderwire was a purely audio medium. Except for an "on" light, it had no other visual interface or cues.

- The audio was high quality, such that users could easily distinguish one another's voices as well as overhear background sounds. The sound quality made it possible to hear everything one might hear sitting in a person's office, including private vocalizations, phone calls, bodily noises, and background noise.

- All messages were public on Thunderwire.

- System use was fluid. People could connect or disconnect themselves from Thunderwire any time they wished, simply by flipping a switch.

- The act of connecting or disconnecting was indicated only by a barely audible click. In fact, there was no way to know exactly who was listening without asking.

Users used desktop microphones, headphones, and controllers with three settings: Off, Listen-only, and On. There were on-off indicator lights for the microphones, and the sound volume could be adjusted. Ten Thunderwire stations could be linked together.

Finally, the Thunderwire system was robust. It was continuously available during the field study.

RESEARCH STUDY AND USE
As mentioned, we chose to study Thunderwire within a field setting to better understand how potential users would view an audio space (if one were to exist). This field study of Thunderwire lasted slightly over two months, and because of the technical requirements, included only one group within Interval.

Before describing the findings from the field study, however, this section describes the field setting, basic usage patterns, and the users' self-reported evaluations. This is necessary background for understanding the field results .

The study group
The group using Thunderwire consisted of nine people, seven of whom were engaged in video editing and analysis. The group members themselves were generally young (often just out of college) and were not permanent staff members. In fact, two group members worked for subcontractors to Interval.

Each person concentrated on separate tape segments, so the work was independent yet closely parallel. Tight coordination was not required, although sharing analytical approaches and problems was helpful, as it might be in, for example, a newspaper office. One consequence of the work was that users were already listening to videotape over headphones, so using headphones for Thunderwire fit well into the existing work practice.

The group also included a manager as well as a software engineer. The manager of the group was older and more authoritative. The software engineer reported to another group, and was not well known to the group before the field study. He was actively supporting and improving an analysis tool for those group members editing video.

This team was largely cohesive before the system was introduced. Most of the group knew each other well; they had spent the summer collecting field data together. As the manager said, "They spent the summer brushing their teeth with one another." All reported that over the summer, they had formed a cohesive social unit. Nonetheless, there were a number of personality tensions at the beginning of the study. As well, two of the nine group members were considered quite independent, and three others were outsiders in some way. One person had become an outsider during the summer, even self-identifying that in that role repeatedly. There was also one other outsider who was a subcontractor and incidental to Thunderwire usage. The last outsider was, as mentioned, the software engineer who was not known to the group before Thunderwire use began.

There were several possible obstacles to adoption and use. Most of the Thunderwire participants sat in cubicles within 100 feet of one another; therefore, the Thunderwire system vied with face-to-face interaction for many members of the group. (The group manager, as well as the software engineer, were in another building.) Moreover, while it was in the group leader's interest to have closer communication with group members, it was not necessarily in the staff members' interest.

Methods and data
Data were gathered using multiple methods. Users' experiences with Thunderwire were studied over the two-month period through interviews, transcripts of use, usage logs, and direct observation, as follows:

- Semi-structured interviews were conducted with the Thunderwire participants before they obtained the system and at the end of the study period. The pre-introduction interviews examined group cohesion, group tensions, and communication patterns. The final interviews were conducted after the field study, and additional interviews with key members were conducted approximately two weeks later. The final interviews were audio-taped and transcribed; the other interviews were captured in detailed hand-written notes.

- Approximately two weeks of conversations, after the adoption phase, were tape-recorded (with the participants' permission), and approximately 18 hours of audio were selected for literal transcription. Conversations entirely and partially on Thunderwire were transcribed in detail; Appendix A shows a portion of one transcript. Short interactions, those taking less than a minute, were missed because of the sampling technique for the tapes. However, one of the authors listened to several tapes to get a sense of these brief interactions.

- Additional qualitative data were obtained through direct observation, examination of source materials, and data reviews. The pre-introduction direct observation was extremely limited.

- Quantitative dabta were obtained through general usage logs and survey data.

The qualitative data analysis included a careful examination of the transcripts and field notes. The transcripts and field notes were coded for common topics and interaction patterns [7, 19]. The quantitative and qualitative data were used to corroborate each other during analysis.

Only the non-Interval authors have had access to the audio data, as well as much of the interview data, to provide confidentiality to the study participants. All data discussed below have been made anonymous.

System use
In general, system acceptance by the socially central players was quickly accomplished. This was absolutely critical to

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adoption and use, as Kraut et al.[16] and others have found. Central members of the group, where centrality implies social position rather than a work or task attribute, adopted the system earlier and used the system more. The exception was the software engineer, who was at first marginal to the group, then played a central role in the system, and later was accepted as part of the core group.

Two users formed the core of Thunderwire participation, using their stations actively and through much of the day. Three others often used the system (for a considerable portion of the day but not every day), and three others seldom used the system. The station in the group's collaborative space was used extensively but passively by the last group member and in varying amounts by the other participants. This pattern roughly followed the exponential curve found in many computer-mediated communication systems [11].

Continued use of the system was fragile. For example, during one observation period, one and then the other key participant was absent for a day and a half, and as a result, there was almost no use of the system.

Usage patterns
System use varied considerably. It was possible to be continuously connected to Thunderwire; it was not uncommon to find study participants connecting to Thunderwire first thing in the morning and disconnecting when they left at night.

"Live mike" time fluctuated somewhat from week to week, but averaged just over two hours per station per day, or approximately 25% of working hours. Since stations could be on without being used (e.g., left on in an empty office) and since "listen only" mode could not be distinguished from the system being completely off, these are only approximate measures of system use. This average also masks the large amount of individual variance; the standard deviation was slightly larger than the average itself.

A better measure may be the number of live microphones. The system often supported two or three active participants, but use by larger groups was relatively rare.

Several uses of the system were innovative and surprising. One participant had Thunderwire jacked in as one of four audio inputs. Not surprisingly, this person was often a passive user of the system. Participants discussed whether they could share music through the system; they discovered that they could, but it would drown out conversation. Users also used the system to ask one another where a person was in transit through the buildings. Participants often inquired after their manager and one another.

Users' evaluations of Thunderwire
In the final interviews, participants were asked to describe Thunderwire. Most of them provided a functional description. Additionally, all but one added comments about the sociability of the Thunderwire space:

> Let's see, I'd probably describe it as ... like an intercom that you can turn on and off and sort of plug into a party line and where ... you can hear

other conversations or participate in a group conversation or try to find a single person on the system to exchange information. -- John

> It's kind of an open line so whoever's on, you can hear -- Patrick

Users not only noted the sociableness of the environment, they also noted the telepresence aspects of the system:

> I think another, in a way a social atmosphere is helped with Thunderwire to create kind of a "hi, how are you doing" ... [a] lightweight-sort of social space that people can join or not join if they so choose. -- John

> ...It's as if in certain ways if there were four or five other people with their desks all right around mine without these little partitions between them, except that we don't raise our voices to talk to each other, and it's kind of everyone's at their own discretion for how much they're participating. -- Rob

While these self-reports are interesting, it should be noted that the adoption process could have promulgated and sharpened this view with the users. Because the manager obtained the system to consciously create a virtual space for the work group, the users could have merely reflected the manager's arguments about community and telepresence. All that can be safely concluded is that the system did not counter this initial understanding on the part of the users.

Not all of the evaluations were positive. In fact, most were mixed. While the system afforded useful interactions—and these interactions, as will be seen below, were enjoyable as well as useful—the users had to struggle to define and regulate their space. These struggles will be detailed below.

The paper next turns to the possibilities and problems of Thunderwire. The following analysis shows that this audio space was both quite similar to, and quite different from, everyday social spaces as well as other types of media spaces.

INTERACTION CAPABILITIES
An important consideration for media spaces is the range of interactions possible within the system. Based on Dourish et al.'s [6] experiences with a continuous audio connection, one important type would be sociable conversation. This was also the case with Thunderwire. These sociable conversations were quite remarkable; they show considerable social interchange, play, and personal warmth.

The following analysis draws on the work of Isaacs and Tang [14], who describe the "rich interactions" possible on their system. In their comparison of video against telephone and face-to-face interactions, they defined rich interactions to be those requiring visual cues and geographical presence. In our study, we have extended their consideration of interaction types to include non-visual considerations such as conversational fluidity, topic flexibility, and conversational conventions.

Providing rich interaction is likely to be critical to workplace acceptance. As Isaacs and Tang state:

> ...we suspect that richer interactions are likely to lead in the long run to more and/or higher quality results. ([14], p. 199)

Rich interaction may include lengthy, intimate conversations, but within a workplace setting, rich interactions may include very informal and unstructured exchanges. Whittaker et al. [28] showed that informal workplace interactions are frequent, brief (usually two minutes or less), and do not include specific initiation and closing utterances.

An extended example (see Appendix A) demonstrates the sociability and richness of Thunderwire interactions. The interactions presented in this example are quite common in the data, although Appendix A's example does bring together a number of issues we wish to discuss.

It is very difficult to convey the tone of this conversation in print. The banter flows naturally, although with a staccato rhythm as the conversation lulls and restarts. Within a fragment, the conversation easily bounces back and forth among group members, one turn often following immediately after another, almost without pause. The following excerpt is typical in its informality and spontaneity. The two "Welcome back" greetings overlap considerably. (For a complete explanation of the transcription notation, see Appendix A.)

1	Mike	I'm back.
2	Rob	Mmm,
3	Patty	[with mock heartiness] Wel/come back\
4	Rob	[joining Patty] \welcome back/

There are several fragments to the conversation in the extended example, with little connection among the fragments. In turns 5 through 11, the three participants discuss a cartoon. From turn 12 through turn 30, the participants discuss names. From turn 32 through 36, they discuss keyboards. (Some turns have been omitted to save space, and some fragments are longer than they appear.)

Many conversations on Thunderwire show no formal beginning and ending points, unlike telephone conversations [13]. For example, after a one-minute pause, Rob reopens the conversation in turn 32 with a gambit, but this gambit is informal and conversational.

| 31 | | [1:04 min. pause. Typing, short amount of someone whispering to himself.] |
| 32 | Rob | Such a difference a real keyboard makes. |

The interaction pattern is similar to being face-to-face in a common room.

Of particular interest is the overlapping speech pattern. In addition to the overlap seen in turns 3 and 4, above, overlap occurs prominently in turns 10 and 11, 14 and 15, and 20 and 21. Several other pairs include overlaps between speech and laughter. This pattern is quite similar to that of face-to-face interaction [20] and dissimilar to telephone or low-bandwidth media [13, 20, 22].

The playfulness in the exchanges is also notable. In turns 12 through 30, the participants unself-consciously make fun of their own names and those of others—perhaps by extension, their identities. In the conversation fragment from turn 39 to 45, excerpted below, Patty is waiting for a phone call to be completed.

39	Patty	[evidently on phone] Yes, is Sarah Altman there? ... It's her friend Patty Chapman. ... [Into Thunderwire] They always ask me [mock politeness, official tone] And what organization are you with?
40	Mike	I see ... and so you say you're a friend
41	Patty	So I'm, I'm trying to cut out that line of questioning.
42	Mike	I see. Or you should say, my dear, her deeply rooted enemy [Patty and Mike laugh.] [1 sec. pause] Just say [in crabbed, old voice] Ven-det-/ta\

Interestingly, she continues on Thunderwire commenting on her call, until the call goes through, at which point she disconnects from Thunderwire. (This disconnection norm for phone calls will be discussed below.)

43	Patty	[using the same crabbed voice] \It's a/ personal call [both laugh]
44	Mike	[3 second pause] tiz pretty funny. [4 sec. pause.] [repeating in old voice, half to self?] Ven-det-ta
45	Patty	[22 sec. pause, typing] Hello. ... Is this the woman who I assume is turning 29 today? [slight male laughter] Happy birthday. So are, you like, being showered with gifts and presents and ... food and stuff? ... [surprised] Twelve! ... Man, you did [Patty disconnects]

In this fragment, Mike and Patty joke back and forth in assumed voices. The use of mediated voices and wordplay was quite common with Thunderwire participants.

Again this exchange is friendly, playful, and close; the data clearly show spontaneous, personal, and highly social interactions. In this conversation and many others, there appeared to be a high level of interaction and informality.

There were also several other conversation types. A number of exchanges provided Thunderwire members with a sense of participation and background information. These

include mouse clicks, paper rustling, background conversations, phones ringing, and people moving through the building. Several group members, in their final interviews, spoke at some length of enjoying knowing what was going on in their group, and users spoke of overhearing their manager's conversations with other group members. Of course, these exchanges and their social advantages trade off against individuals' needs for privacy; this was a constant tension for the group.

Rather surprisingly, there were only a handful of information exchanges about work tasks. Users seldom interacted over the system about the details of their work. This may have been due to the visual nature of the group's work (video-editing), the individuals' work patterns (editing and composing is individual work), or the system's affordances. This issue should be examined further in subsequent studies.

Nonetheless, the data overall, as seen in the examples, indicate that the study participants had very rich interactions, especially sociable interactions. Particularly notable is the degree to which people were able to fluidly socialize and interact through Thunderwire, unlike with low-quality audio and telephone systems

The ability of participants to conduct rich interactions is an important aspect of audio spaces. If people could converse freely and interact in everyday ways on a system, they should be more willing to use it over an extended period. The following section further examines interactions within the social space and suggests how audio spaces might differ from other media spaces.

NORMS FOR A SHARED SPACE

The data, especially the audio transcripts, show a set of norms related to Thunderwire use. As one might expect, the group negotiated shared understandings [27] of what to do on the system, developing norms in reaction (a topic also explored in [1]).

A general definition of norms is "group-supported definitions of expected behaviors in specific situations" [17]. More importantly, as Feldman states:

> ...a group does not establish or enforce norms about every conceivable situation. Norms are formed and enforced only with respect to behaviors that have some significance for the group. ([8], p. 47)

The major norms for the Thunderwire users concerned the side effects or results of a shared social space: dealing with noise, knowing when someone was present, knowing when someone was listening, and limiting violations of personal privacy. While the Thunderwire participants were only partially successful (from an outsider's viewpoint) in dealing with these issues, that they struggled with these issues reflects not only some problematic aspects of an audio-only space but also the social possibilities of being within a telepresent space.

The remainder of this section discusses two norms that best typify Thunderwire's shared audio space. These norms were

repeatedly observed within the data. The first norm concerns announcing signing off and on to the system, and the second norm concerns inattention and withdrawal.

Announcing oneself

One of the major problems for Thunderwire users was not being able to easily tell who else was within the space. Thunderwire shares this problem with other shared media systems that do not make public who is on the system. (Even some systems that do make users publicly known can have this problem, if the system is inconsistent or tardy in updating the user list, or if the system is not completely believed by the users.) However, not knowing who is on the system is particularly acute in an audio-only space.

There were three methods for knowing who was on the system: verbally signing onto Thunderwire, asking who was on the system, and verbally signing off the system. All were inherently imperfect, since a user could evade the norms. However, social sanctions (e.g., derisive comments) were applied by group members to those who were caught.

Signing on. In turn 1, above and in Appendix A, Mike announces himself as he joins the Thunderwire space. Because Thunderwire participants were not visible to each other, it was common for group members to notify and greet each other when they entered Thunderwire. Additionally, participants often thoughtfully updated new arrivals when they signed on, letting them know who else might be on the system.

Interestingly, the audible click of a microphone being switched on or off served as a resource for group use. Although one might have perceived the click as annoying and assume it should be removed, participants used the click to know when people were joining or leaving the discussion. It was usual for someone to announce their presence. If a click was heard without an announcement (as the second author did once early on), someone asked who it was.

Signing off. Thunderwire participants usually let one another know when they were leaving the system as well, as can be seen in turns 37 and 38, below.

| 37 | Rob | [clears throat, 2 sec. pause] I'm gunna go [tearing sound] try and find a couple tapes. |
| 38 | Mike | Take care, Rob. [1:55 min. pause. Patty whispers to self? Typing, mouse clicks] |

This enabled people to know who was still on Thunderwire.

Telephone calls. One of the most obvious norms concerned telephone calls. Simply stated, if a user received or initiated a personal phone call, he was supposed to leave the Thunderwire space for the duration of the call. The sign-off norm did not extend in this situation; telephone calls were signaled on the system by the ringing sound or the participant's initial interaction with the call.

While this norm superficially appears obvious—listening to other people's phone calls is disruptive and invades privacy—the norm is particular to audio spaces. In face-to-face encounters, one generally does not leave the room under similar circumstances. It is normally acceptable to attend to a personal call while in the presence of others; indeed, it might actually be considered rude, somewhat odd, or suspicious if one were to excuse oneself. There is a strong possibility, then, that this norm was formed in response to the particular challenges posed by an audio-only space.

A very interesting example of the telephone norm occurs in turns 39 through 45, shown above and in the appendix. Patty disconnects only after the call goes through, spending the intermediate time discussing the phone call over Thunderwire.

Inattention and withdrawal
In an audio-only environment, many of the visual cues that a person may normally use to avoid unwanted interaction in a socially acceptable way are not available. It is not possible to either establish or avoid eye contact, and it is not possible to adjust one's visibility. Therefore, there is no easy way to determine from a distance one's willingness to interact—one cannot close the door, avoid another's gaze, appear busy, frown, or appear intensely engaged. On the other hand, every utterance by any group member is heard perfectly and equally well by every other group member, and therefore one cannot plausibly pretend he did not hear another participant talk to him. Nonetheless, for the system to work, group members needed to find mechanisms through which they could signal when they were more or less desirous of social contact.

When users were preoccupied, it was important for them to be able to pay minimal attention and to be able to both signal this request and have it be accepted in a socially acceptable manner. Without this ability, participants would have to withdraw from Thunderwire space whenever they needed to concentrate or pay attention elsewhere. In general, Thunderwire participants signaled their inattention by pausing or uttering fill words in a distracted tone. For example, in the following exchange, John mutters "uh-hm" very slowly and without interest to signal his preferred inattention. This is the more remarkable because Patty addresses him directly:

1	Patty	John, are you there?
2	John	Um-hm.
3	Patty	Thanks for this New York thing.
4	John	Um-hm
5		[Typing, mouse clicks, male clears throat]

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John's brief responses signal that he is uninterested in further conversation, and the exchange ends. Nonetheless, John is still capable of paying some attention (i.e., maintaining his system presence without having to completely withdraw). Indeed, John later asks Patty about her conversation with the group's manager, a conversation heard on Thunderwire.

Another mechanism for signaling partial attention was to just let the conversation lapse. While this might seem odd compared to many face-to-face interactions, this type of conversation lapse does occur in many workplace conversations [28]. This occurs in the Appendix A example. A lull in the conversation is followed by turn 7, a new opening where Mike starts another extended conversation over the system. In other situations, the conversation slowly winds down as the participants do not revive it.

In face-to-face behavior, one of the ways that people avoid blatant rejection is to use subtle, non-verbal cues to signal and to determine the possibilities of social contact [15]. Inattention and withdrawal were very public in the Thunderwire space, and the signals were more explicit than one might prefer. Therefore, group members appeared to have devised other means to gracefully terminate unwanted social interaction. Problems with the headphones were a common experience, and withdrawal blamed on apparent equipment failure was generally unquestioned.

Norms and audio affordances
In this field study, participants formulated and maintained the above norms as well as many others. The particulars of these normative mechanisms were idiosyncratic to the individuals involved, but it must be stressed that the underlying requirements for *some* norms dealing with these issues were not [5]. Users had to adapt to many audio-only conditions (e.g., lack of cues before loud noises) and system conditions (e.g., the inability to tell who was on the system).

It must also be emphasized that the construction of these norms would not have occurred unless the participants felt they inhabited a space together. The Thunderwire participants constructed these norms to deal with real problems in the Thunderwire space. And, they would not have been able to construct these norms or maintain them without their active participation within a common social space. This was clearly a social space, and the existence of these norms was a strong indication of telepresence.

CONCLUSIONS
This study began by questioning whether audio alone was suitable for shared media systems and if so, what we could say about the resulting social space. The system that we examined, Thunderwire, included good-quality, full-duplex audio without lag; persistently available group communication capable of conveying ambient workplace sounds; an audio-only user interface; and a simple model of user control.

Our field study of Thunderwire use suggests (with the standard limitations of case studies):

- *Audio can be sufficient for a usable media space*. Thunderwire users conversed sociably and in what appeared to be a natural manner. Many of the

conversation characteristics, such as turntaking and overlapping speech, were in notable contrast to low-quality audio use, such as one finds with the telephone.

Nonetheless, the field study clearly suggested that some user interface mechanisms need to be improved in future audio media spaces. Users would prefer to know who is present in the audio space. The low disturbance audio explored by Smith and Hudson [26], where users can hear who is speaking without hearing the words themselves, is one possible solution. Additionally, some automatic mechanism for turning off microphone input during an incoming telephone call would have been helpful. Furthermore, allowing users to set up two-way, private conversations might have been useful, as has been suggested for video media spaces. None of these interface changes, however, would require a visual interface; all could be incorporated within an audio-only environment.

- *Audio spaces can lead to social spaces.* Thunderwire afforded a social space for its users. Evidence for this included user evaluations and more importantly, existence of norms regulating social use of the space by group members.

  That participants worked out common issues within this space argues that Thunderwire was a telepresent environment, even without visual cues. On the other hand, this study also suggests that telepresence is hardly a uniform phenomenon. The nature of the space itself was important to the participants' sense of social space.

- *The nature of these social spaces is affected by audio's affordances.* Thunderwire users created and maintained norms in response to concerns that are either specific to an audio-only environment or are exacerbated by an audio-only environment. However, the users created and maintained these norms with effort. Adapting to a shared public space was an especially acute issue for the Thunderwire participants.

Thunderwire, as an audio-only environment, appears to have had certain *media* properties that had to be considered and potentially dealt with by group members. These media properties created certain *social* conditions (or rather allowed them to occur) for the study participants. While one could also imagine other responses (e.g., resistance to adoption or inter-personal conflict), the interesting point is that group members had to change their behavior in response. While the specifics of the response may differ from system to system, and from group to group, the need for some response to the media and technology affordances will not. Thus, this and other examinations of social use will not only guide the design of media spaces, they can also bring us to a better understanding of audio and other media in general.

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APPENDIX A: SAMPLE CONVERSATION

In the transcription, the angle brackets <> indicate a section of the tape that was indistinct. The square brackets [] indicate external sounds or an inference on the part of the transcriptionist, data analyst, or researcher. The slashes \/ and /\ indicate overlapping conversational areas on the tape; a = sign indicates that there was no appreciable pause between the two words. Three dots ... indicate a short pause; longer pauses were indicated by a description of the pause, as in [pause 1.5 minutes]. Portions of the transcript were omitted for lack of space. These are marked where they occur.

1	Mike	I'm back.
2	Rob	Mmm,
3	Patty	[with mock heartiness] Wel/come back\
4	Rob	[joining Patty] \welcome back/
		(segment of conversation omitted)
5	Mike	Oh, there was this hysterical cartoon somebody put on the library bulletin board [Patty laughs slightly] It's a Berkeley Breathed cartoon about Tammy Baker ...
6	Patty	[with interest] Yeah?
7	Mike	and it's [next word drawn out] really [laughs a little] wonderfully mean. So I recommend it if you
8	Rob	/<inaudible>\
9	Mike	\haven't/ seen it
10	Patty	/[giggles]\

11	Rob	\[laughing slightly] Alright./ [20 sec. silence. Sounds like can rattling, typing.]
12	Mike	Well, Susan Belman's middle name is Evangeline. ...
13	Patty	Yes=
14	Rob	=That is a /fact.\
15	Patty	\It's in/ all of her e-mails=
16	Mike	=That's pretty remarkable. ...There are so many special people here. [Patty and Rob laugh]
17	Rob	Maybe I should start calling myself Rob [emphasis] Steven [ends emphasis] McLaughlin
18	Patty	What was it?
19	Rob	Steven.
20	Patty	[confirming, considering] [drawn out] St/even\
21	Mike	\Steven/ just doesn't have it quite like, I mean I'm sorry but it [Rob laughs] doesn't have it like [dramatic pause] Evangeline
22	Patty	/[laughs]\
23	Rob	[breathlessly] \Evangeline/
24	Mike	Well, geez, I think I'm gunna change my name to Evangeline. [slight laughter] A-, in fact, that sounds pretty good, Evangeline Angora Thompson
25		/[Patty laughs]\
26	Rob	\[appreciatively, laughing] Wooo-hooo-hoo-hoo-hoo-hoo!/
27	Mike	Ah, jeez, a whole new me.
28	Patty	It definitely ... is ... evocative of so- ... a certain something, I'm not quite sure=
29	Mike	=Not quite sure, don't want to think of too much about what [laughing] exactly it's evocative /of\.
30	Patty	\[laughs]/
31		[1:04 min. pause. Typing, short amount of someone whispering to himself.]
32	Rob	Such a difference a real keyboard makes.
33	Mike	Yeah?
34	Rob	Yeah, I can type a lot faster now that I have
35	Patty	Yeah, I was making so many mistakes when I had ... [rising] just the little PowerBook.
36	Rob	[2 sec. pause] It's just a different feel to the keys.
		(segment of conversation omitted)
37	Rob	[clears throat, 2 sec. pause] I'm gunna go [tearing sound] try and find a couple tapes.
38	Mike	Take care, Rob. [1:55 min. pause. Patty whispers to self? Typing, mouse clicks.]
39	Patty	[evidently on phone] Yes, is Sarah Altman there? ... It's her friend Patty Chapman. ... [Into Thunderwire] They always ask me [mock politeness, official tone] And what organization are you with?
40	Mike	I see ... and so you say you're a friend
41	Patty	So I'm, I'm trying to cut out that line of questioning.
42	Mike	I see. Or you should say, my dear, her deeply rooted enemy [Patty and Mike laugh.] [1 sec. pause] Just say [in crabbed, old voice] Ven-det-/ta\
43	Patty	[using the same crabbed voice] \It's a/ personal call [both laugh]
44	Mike	[3 second pause] tiz pretty funny. [4 sec. pause.] [repeating in old voice, half to self?] Ven-det-ta
45	Patty	[22 sec. pause, typing] Hello. ... Is this the woman who I assume is turning 29 today? [slight male laughter] Happy birthday. So are, you like, being showered with gifts and presents and ... food and stuff? ... [surprised] Twelve! ... Man, you did [Patty disconnects]

111694.1:27-31