Social Presence with Video and Application Sharing

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ABSTRACT
We present two experimental studies examining the effects of videoconferencing and application sharing on task performance. We studied performance on a cognitive reasoning task while subjects were observed via two-way video, one-way video and application sharing. Results demonstrate that performance is impaired when subjects are observed via media compared to when they are not observed. Surprisingly, we found no significant difference in awareness of the observer's presence between the application sharing and the two-way video conditions. This is surprising because application sharing lacks visual feedback of the observer. This finding contradicts social presence theory which claims that media which provides visual feedback of others produce the greatest sense of social presence. Our data also show that media use heightens the perception of task difficulty. We extend social presence theory and argue that these social effects need to be considered in the design and deployment of video and application sharing technologies for use in the workplace.

General Terms
Management, Performance, Design, Experimentation, Human Factors.

Keywords
Video conferencing, application sharing, distance collaboration, social presence, social affordance.

1. INTRODUCTION
In the past several years, we have seen an increased reliance on distance collaboration in the workplace. Virtually collocated workteams are now using a wide range of technologies to engage in real-time collaboration including audio conferencing, video conferencing, chat, application sharing, and media spaces. Yet as these technologies become more commonplace, our understanding of productivity issues and social effects surrounding such technologies remains vague [8]. Learning about these effects can inform us better in the design, placement, configuration, and choice of different media to connect remote team members.

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Collaboration involves shifting between individual and group work. People may work collectively, or may divide up their labor. All phases are part of collaboration, including individual work that is done in a group context. The same is true when using technology to work virtually collocated. We must however keep in mind that different technologies convey different social cues. For example, video conferencing tools maintain an audiovisual channel of communication between conference sites; individuals may work in parallel, or one may work while others observe. Transitioning between group work and individual work is a matter of engaging turn-taking rules of conversation. While video may provide such cues to aid people in shifting turns, with application sharing, cooperating partners must explicitly indicate that there is a turn shift. Floor control mechanisms in most application sharing tools do not afford such natural turn taking; the user who has control of the screen has 'the floor' and works at the screen alone while others observe and until she explicitly passes control to another meeting participant. Thus, even though one team member might be working and the other observing, both are involved in a collaborative process.

In this paper, we explore the notion that electronic conferencing technology, while not only providing a means of efficient information exchange across distance, can also be a conduit of social information about other team members [9]. Researchers in the field of group and organizational psychology have long been aware of the role that social information plays in collaboration, for example, in developing cohesion and trust among co-present collaborating partners [13]. However, in many collaboration contexts today, collaborators are not co-present. Instead, collaboration is mediated by collaboration technology which provides only a mediated experience that another individual is "present" [18]. But the effects of mediated presence are not well understood. In this study, we focus on this aspect of technology use across distance: the ability of a particular technology to convey a sense of *social presence* of a collaboration partner.

1.1 Social Presence
In a seminal study of teleconferencing by Short, Williams and Christie [24], the authors present the theory of social presence to explain the extent to which different media convey social cues. Conceptually similar to social affordance theory [3], social presence is defined as a quality of a given media that affects the degree of salience of a conversational partner in a one-to-one interaction. As Short et al. describe, audio and text media fail to convey a number of visual cues present in face-to-face interaction, such as facial expression, eye gaze, gestures, and proximity. The degree of social presence of a given media is determined by the extent to which it conveys these non-verbal cues.

The theory of social presence has proven to be compelling to technology researchers [26]. The role of visual and nonverbal cues in media has been studied with video conferencing technology [6], e-mail [25] and has been used to compare different media [5, 23]. Some studies have focused on identifying which tasks are sensitive to non-verbal cue effects and how communication and performance are affected over time [7, 14].

In this study, we compare how a sense of social presence is conveyed with video and an emerging technology: application sharing. Application sharing enables geographically distributed users to view and interact with the same software application simultaneously. It is proving to have collaboration benefits compared to audio-conferencing alone [19].

Following social presence theory, we argue that the impact of a remote coworker on work performance is related to the degree of social presence that the media conveys. With respect to collocated team members, a large body of research has shown that, compared to being alone, the mere physical presence of another person can cause people to perform worse on complex tasks, explained through either social facilitation (e.g., [27]) or evaluation apprehension (e.g., [4]). We would expect similar results when people use a conferencing technology, depending on the degree that the media conveys a sense of presence of another person.

Prior research suggests that, compared to teleconferencing, the high number of non-verbal communication cues conveyed by video affects collaboration [7, 15,]. For example, video has been found to improve the ability to show understanding, forecast responses, and express attitudes [15]. While the effects of video have been demonstrated, it is not clear how or whether application sharing media, which provides no visual cues of collaborating partners' face or body, would impact performance.

Video-conferencing and application sharing media provide two different sources of information for collaborating partners. Video conferencing provides information about a person: facial expressions, gestures, eye gaze, and body position (the decipherability of these depends on the resolution and frame rate of the video). Application sharing, on the other hand, provides information about the task. The smallest cursor movements of one person can be easily detected on another person's screen. During our past field studies of application sharing, users reported that they felt "inhibited" or "exposed" to the group when using application sharing. They attributed their exposed feeling to the fact that their smallest screen actions were visible to all others in the group.

In light of these reports from users, and considering the different visual information conveyed by video and application sharing, we asked the following research question: does application sharing technology create a virtual "social presence" such that the effects on performance can be measured? To address this question, we conducted two experiments examining the effects of video and application sharing on performance. We expect our results will be useful to groupware researchers, software designers, and managers of geographically distributed knowledge workers who use computer-mediated communication technologies.

2. STUDY OVERVIEW

We conducted two experiments examining the effects of social presence on task performance. Both studies used the same task, setting, experimental design (repeated measures between-subjects), procedures, and measures.

2.1 Task

We selected a computer-based math task to simulate a cognitively demanding task that a knowledge worker might engage in during real-world, technology-mediated meetings. Because it involves logical problem solving, we feel that solving math problems simulates an intellectually challenging task, such as interpreting spreadsheet data, estimating costs, scrutinizing decision rationale, analyzing project tradeoffs, or examining technical documents such as engineering drawings or programming code. It is important to note that we have deliberately selected a logical reasoning task to simulate tasks common to groups that actively collaborate while in technology-mediated meetings. Such tasks are characteristic of the geographically distributed project teams, i.e. 'virtual teams,' examined by Poltrock and Engelbeck [22] and Mark et al. [19].

For the math task, subjects were given ten math problems to solve. They had to combine three numbers using any of four operators (plus, minus, multiply and divide) to produce a given solution. All problems were solved in two steps. Subjects were not permitted to skip any problem. For each condition, a unique set of ten problems was randomly selected from a large set of problems.

2.2 Experimental Setting

The experiment was conducted in two offices in the same hallway, on a university campus. The subject sat in one room in front of a computer. A digital camera was positioned to the left of the monitor. The camera lens[1] was positioned at the same height as the top of the monitor. A 24-inch diagonal monitor was positioned immediately to the right of the subject's computer monitor, and displayed either the observer's face or a garden scene. The video monitor was placed at a distance determined to be outside the 'personal' space of an American [12]. When the observer was displayed, the dimensions of the observer's face and torso were judged to be roughly equivalent to the true dimensions were she to physically sit where the video monitor was placed. The observer appeared to be looking directly at the subject.

The observer sat in the second office. One computer displayed the subject's screen via application sharing; a second computer displayed the subject's image via the video connection. A video camera in this office recorded either the observer's image or a garden scene, and sent the image to the video monitor in the subject's office.

2. 3 Measures

The following measures were taken during the experiment:

[1] The subject was briefly shown their image on the small LCD screen of video camera before each video session. However, the LCD display was obscured from view throughout the remainder of the session. This was done to prevent the subject from being distracted by their own image.

Math performance. The time taken to solve a set of ten math problems was measured using a digital stopwatch.

Attitudes about the task. A questionnaire measured attitudes on ability to concentrate, alertness, awareness of being observed, distraction, pressure, motivation, concern for mistakes, and awareness of the presence of others.

Perception of task difficulty. In the questionnaire, subjects rated how difficult they perceived the task to be.

2.4 Experimental Design

We used a repeated measures (Media Connection), between-subjects (Media Type) design (see Table 1). To minimize any practice or carry-over effects, the order of the conditions was counterbalanced within-subjects.

Factor	Levels of Factors
Experiment I	
Media Connection (within-subjects)	Off (Alone) On
Media Type (between-subjects)	2-way Video Application Sharing
Experiment II	
Media Connection (within-subjects)	Off (Alone) On
Media Type (between-subjects)	2-way Video 1-way Video

Table 1. Experimental design

Subjects

All participants were undergraduates in a Computer Science department at the University of California, Irvine.. All were naïve to the purposes of the study. The population was selected to minimize variability between subjects in math ability and computer experience. All participants were paid $12.

Procedure

Both experiments lasted one hour. Subjects were first trained: they solved as many sample problems as they could in four minutes. Following training, subjects performed the math problems either: a) alone, and then with a media connection, or b) in the reverse order, with media and then alone. Subjects were instructed to do as well as they could and were told their scores would be recorded for data. After performing each set of math problems once, subjects filled out a questionnaire. A tape-recorded interview was conducted at the end of the experiment.

3.0 Experiment I

In this experiment, we tested the effect that video and application sharing each have on a person's task performance. Thirty-three subjects participated in the experiment (64% Male and 36% Female). Each subject was randomly assigned to one of two conditions, counterbalanced to minimize order effects:

Alone and 2-way Video (A X 2V)

In one treatment condition, no collaboration media were used – the subject was told that s/he would be performing the task while alone in the room. In another treatment condition, the same subject was instructed to perform the task while a video monitor displayed the observer's head and upper torso, life-size and with television quality. An audio connection via a speakerphone was also used. Subjects were informed that the observer (second author) would watch them through the video as they performed the task.

Alone and Application Sharing (A X AS)

In one treatment condition, no collaboration media were used – the subject was told that s/he would be performing the task while alone in the room. In another treatment condition, the same subject performed the task while an application sharing program, Microsoft NetMeeting^{tm}, replicated the subject's screen on the observer's screen. Before the application sharing condition began, the observer briefly demonstrated the program by controlling the cursor and using the math software. The demonstration continued until the subject confirmed that s/he understood that everything that appears on her/his screen is visible on the observer's screen. An audio connection via a speaker phone was also used. Subjects were informed that the observer (second author) would watch their screen via the application sharing as they performed the task.

In all observed conditions, the observer remained expressionless and relatively silent, intermittently coughing and rustling papers.

3.1 Results

Table 2 presents the results from Experiment I. We had expected to find that video, because of its visual cues, would affect performance, but not application sharing. Instead we found that both video and application sharing show performance effects for the math problems.

Task performance.

We measured the time taken to solve ten math problems. An ANOVA showed a significant difference for Media Connection ($F(1,31)=4.89$, $p<.035$). It took a minute and a half longer, on the average, for subjects to solve the ten problems with either two-way video or application sharing turned on, compared to being alone, without any media. There was no significant difference for Media Type ($F(1,31)=.24$, $p<.63$), and no significant interaction of Media Connection x Media Type ($F(1,31)=.91$, $p<.35$).

Perceived difficulty of task.

On a six-point scale (1 = Strongly Disagree, 6 = Strongly Agree) an ANOVA performed within-subjects showed that the math task was judged significantly more difficult when subjects were observed. Although the very same task was presented, subjects rated the task the hardest while performing with video 'on', next hardest when application sharing was running, and easiest without media (Alone). The difference was highly significant ($F(1,31)=9.17$, $p<.001$).

Questionnaire.

Table 3 lists mean responses to questionnaire items on perceptions of task performance while Alone and with Media (application sharing or two-way video).

The *t* values indicate the within-subjects effect, i.e. the difference between the Alone and Media condition. Responses were ranked on a scale of 1 = Strongly Disagree, 6 = Strongly Agree. Subjects were aware of being observed while application sharing and video were turned 'on', but not while alone. There was no difference in motivation when two-way video or application sharing were 'on'. As we might expect, subjects felt their mistakes were more visible when application sharing was used.

	Experiment I	Experiment II
N and *df*	N = 33 *df* =31	N = 48 *df* =46
Alone	**542.5*** (233.9)	**412.7*** (153.43)
Observed	**631.2*** (197.0)	**472.7*** (209.80)
Media Type: 2-way video	**633.9** (208.0)	**497.4** (241.21)
Media Type: App. sharing	**628.3** (191.3)	---
Media Type: 1-way video	---	**447.7** (180.79)

*p<.05 parentheses indicate standard deviations

Table 2. Mean time to solve math problems (seconds).

4.0 Experiment II

Experiment I showed that with application sharing as well as video, performance on a complex task was impaired. Two findings from Experiment I motivated Experiment II. First, we were puzzled by the fact that application sharing, which provides no visual feedback of the observer's presence, affected math performance. We felt a clue to the effect lay in the counter-intuitive responses to question 5 (Table 3). Responses show there was virtually no difference in awareness of the presence of another person between the application sharing and video conditions. This finding contradicts the argument that media which provides visual feedback of others produce the greatest sense of social presence [24]. One explanation for this finding is that there is something intrinsic to application sharing, specifically to NetMeeting, which creates a sense of presence of others. An alternative explanation is that *any context* in which computer users are made aware they are being observed through media, even though they have no visual feedback of the fact, affects performance. Findings from Experiment I did not allow us to distinguish between these alternative hypotheses. We tested these hypotheses in the second experiment. In Experiment II, we used a one-way video connection that displayed the image of the subject to the observer but masked the image of the observer to the subject. The subject did not see the observer's face but instead saw a 'neutral' garden scene. In this way, we created a context not unlike the application sharing condition in which subjects were told they were being observed but had no visual feedback to confirm this. Lastly, we increased the math training time in order reduce the possibility that the results were affected by too-little training.

In Experiment II, forty-eight subjects participated (71% Male and 29% Female). Each subject was randomly assigned to one of two conditions:

Alone and 2-way Video (A X 2V)

This was the same condition used in experiment I.

Alone and 1-way Video (A X 1V)

This condition is identical to the A X 2V condition with the exception that the two-way video is replaced by a one-way video connection. Rather than seeing the observer's head and upper torso as in the two-way video trial, the camera is pointed out the observer's window so that the subject sees trees rustling in the breeze. Subjects were informed that the observer (second author) would watch them via the video as they performed the task although they would not be able to see the observer's face.

4.2 Results

In this experiment, we investigated to what extent video-mediated visual feedback of a partner's face affects task

	Experiment I				Experiment II			
Question	Alone	App. Share	2-way Video	*t(32)*	Alone	1-way Video	2-way Video	*t(47)*
1. I was distracted during the task.	**2.55** (1.37)	**3.76** (1.25)	**3.75** (1.61)	-4.474*	**1.85** (0.71)	**3.31** (1.19)	**3.82** (1.18)	-8.529*
2. I was motivated to perform the best I could.	**4.45** (1.25)	**4.35** (1.32)	**4.63** (1.20)	-.133	**4.90** (1.02)	**5.04** (1.04)	**4.73** (1.32)	.001
3. I was concerned about making mistakes.	**4.36** (1.38)	**4.12** (1.36)	**4.69** (1.45)	-.128*	**4.52** (1.13)	**4.12** (1.34)	**5.05** (0.84)	-.127
4. I felt that my mistakes were visible to others.	**3.45** (1.64)	**4.29** (1.49)	**5.56** (0.73)	-4.544*	**3.04** (1.50)	**3.77** (1.56)	**4.60** (0.96)	-4.627*
5. I was aware of the presence of another person.	**2.91** (1.63)	**5.06** (1.20)	**5.00** (1.03)	-8.268*	**2.54** (1.49)	**4.88** (0.86)	**5.31** (0.65)	-10.063*
6. I was aware that I was being observed.	**3.45** (1.66)	**5.53** (0.62)	**5.56** (0.63)	-6.770*	--	--	--	--
7. I was bothered by a lack of privacy during the task.	--	--	--	--	**2.17** (1.17)	**3.35** (1.06)	**3.78** (1.01)	-7.073

*p<.001; parentheses indicate standard deviations

Table 3. Mean responses to questionnaire items in Experiment I and II

performance. We found that a one-way video connection impairs task performance although it provides no visual feedback of the observer. We also replicated findings from Experiment I with two-way video.

Task performance.

An ANOVA showed a significant difference for Media Connection ($F(1,46)=4.540$, $p<.038$). It took approximately one minute longer for subjects to solve the ten math problems while observed via the one-way or two-way video. There was no significant interaction of Media Connection and Media Type ($F(1,46)=.044$ $p<.836$).

Perceived difficulty of task.

Results replicated those of Experiment I: the math task was judged hardest with two-way video, and easiest Alone ($F(1, 46)=8.05$, $p<.007$).

Questionnaire.

Table 3 lists mean responses to questionnaire items (1 = Strongly Disagree, 6 = Strongly Agree) on perceptions of task performance while alone and observed (two-way or one-way video). The *t* values indicate within-subjects effects. Subjects reported being most bothered by a lack of privacy while observed via two-way video. We also verified that they reported being aware of the presence of the observer in the media conditions but not in the alone condition. Not surprisingly, awareness of the presence of another person was highest when two-way video was 'on' and lowest when alone. Yet, the mean scores for two-way and one-way video regarding awareness of the presence of another person are not significantly different from each other. This is surprising considering that the one-way video did not allow subjects to see the observer – recall that the one-way video presented a garden scene to the subject while the observer viewed the subject's image on her screen. It is also interesting to note that there was no significant difference in concern about making mistakes when one- or two-way video was 'on' compared to being alone.

5.0 DISCUSSION

Data from these experiments show that when people are performing a cognitive reasoning task during one-way video conferencing, two-way video conferencing, *or* application sharing, their performance is worse than without another person being connected with them via media. Subjects who solved math problems when an observer was electronically present took 1-1.5 minutes longer to complete the problems. This was a significant difference from when they solved the problems without an observer electronically present.

5.1 Collaboration in the Laboratory

As stated above, we deliberately selected the math task, a logical reasoning task, to simulate tasks common to groups that actively collaborate while in technology-mediated meetings. It was also stated that such tasks are characteristic of the geographically distributed project teams, i.e. 'virtual teams,' examined by Poltrock and Engelbeck [22] and Mark et al. [19]. An open question is: how does performing math problems while being observed by an unknown observer simulate a collaborative work context? The answer is that this experiment, as we have designed it, is not intended to simulate collaboration over time – neither within a single meeting nor across months of a project lifecycle. It falls well short of simulating the diverse tasks representative of virtual team meetings such as greeting participants, reviewing an agenda, presenting a problem, analyzing a problem, planning and scheduling [22]. Instead, our objective was to simulate a very specific 'slice in time' during group meetings. Specifically, our objective was to examine the effects of technology-mediated presence while a meeting participant has the attention of the other meeting participants, and is processing information to formulate a response.

Does reasoning during technology-mediated group meetings warrant a laboratory experiment? We feel it does because it lies at the heart of the question that industry practitioners and groupware professionals alike are concerned with – does technology affect group performance and product quality? During a meeting, group performance and product quality is correlated to each individual's ability to process information and reason about that information in real-time. This is not to say that a group is the sum of its parts. Concepts such as groupthink [16] and social loafing [17] challenge that assumption. However, it is possible that a significant impairment in individual performance during meetings will produce an effect on group performance. Further study is required to determine the directionality of the effect, yet we hypothesize that poor individual performance will produce a net negative effect on group performance. Thus, the aspect of collaboration that this experiment examines is individual reasoning during technology-mediated meetings. The findings from this experiment indicate that individuals perceive reasoning tasks to be more difficult, and that their performance is impaired, when they are observed through video or application sharing compared to when alone. One hypothesis that can be constructed from these findings is that technology-mediated group meetings produce a sense of presence of others that negatively affects group performance. We explore this hypothesis, and possible mechanisms underlying the effect, in the following sections.

5.2 Social Presence

Throughout this paper we have used our two-way video data to conceptually "calibrate" our application sharing data. Doing so caused us to be surprised by the response in Experiment I to the question "I was aware of the presence of another person," with application sharing (Table 3, question 5). We expected subjects to report being much less aware of the presence of the observer while in the application sharing condition compared to the two-way video condition, yet no significant difference in awareness between conditions was reported. In Experiment II, scores for the identical question showed that with one-way video, subjects were about as aware of the observer as with two-way video, even though one-way video offers no visual feedback of the observer. Taken together, these findings from Experiment I and II suggest that visual feedback of a collaborating partner (or observer) is not necessary to create a sense of presence.

Other researchers (e.g., [24]) have used quantitative measures of user perception to determine the relative Social Presence score for different media. Ratings for scales such as "impersonal–personal" and "unsociable – sociable" have been used to rank order media. We have not adopted this approach since our objective is not to rank order media but rather to understand how social presence conveyed by different collaboration technologies affects performance over distance.

In the next two sections we offer two concepts, impression management and visibility, which draw on social presence theory to help resolve how presence is mediated by application sharing technology.

5.3 Impression Management: Task and Person Focus

Impression management refers to the way in which we actively guide and control the impressions others form of us [10]. One means by which we manage others' impressions of us is to adjust our behavior when we are observed. We believe that informing subjects that they were being observed spurred impression management in the application sharing and video conditions in our experiments. This notion is supported by five social psychology studies reviewed in [11] examining the effects on performance due to the presence of an observer. In these studies, a subject performed different tasks while an observer was physically present but was positioned behind the subject. The observer could observe the subject perform the tasks but could not be visually monitored by the subject. All studies found significant effects of presence when observers, in effect, looked 'over the shoulder' of study participants.

With application sharing, an observer can virtually look 'over the shoulder' of another user. In our experiments, a number of participants indicated the desire to "give a good impression" on the screen through application sharing and video. For example, while being observed via video, one subject reported:

> *"When I was being observed, I didn't want to show that I took a little longer to solve the problems."*

In the application sharing condition, many subjects reported that they solved the math problems by "hacking" on-screen while alone but were reluctant to hack while their screen activity was being observed. One subject states:

> *On the math one, I felt like I could experiment and have wrong answers. But while I was being watched [via application sharing], I wanted to think it through my head first.*

By experimenting on-screen, he felt it became evident that he did not know the correct solution. To render his thinking process invisible to the observer, he chose to 'think it through' in his head while being observed.

We interpreted the large number of comments like this to indicate that in the application sharing and video conditions, subjects engaged in impression management while being observed. This theory helps explain the impaired performance on the math task. It is possible that subjects took longer to solve the math problems while being observed due to the fact that they thought each solution through in their heads rather than "hacking" on screen, to more quickly reach a solution to each problem.

Visibility of Errors

It remains to be explained *how* impression management is performed in the application sharing condition. We argue *why* it is performed – subjects want to put on a good face [10] – but we have not established what it is about application sharing that enables impression management. The statistically significant response to question 4 in Experiment I (Table 3) provides a fascinating clue. Responses to the question "I felt that my mistakes were visible to others" indicate that subjects felt that their mistakes were highly visible in the application sharing condition. To better understand the effects of the different conferencing media, we tested eight additional subjects using both the video and shared application, using the same experimental setup. Due to the small sample size, we present only the qualitative data here. Interview data from these additional subjects indicate that subjects are more aware of their mistakes in the shared screen condition due to its immediacy and visibility of errors:

> *On the [video] screen, you're not affecting the person but if what I'm doing is seen on her computer, then she can check what I'm thinking right now. I was more conscious of the errors I was making.*

Thus, perhaps the immediacy and visibility of errors in application sharing alters what is 'salient' in social presence. When application sharing was turned 'on', users were aware that the smallest cursor movements they made were visible to the observer. Recall that subjects were shown that the observer could see their screen and were told that the observer would be watching the screen throughout. Contrast this to video, in which subjects knew the observer could only see their face. One study participant expressed this difference in terms of being 'more conscious,' or salient, of the task versus the person:

> *In the video I felt like she was just looking at my face...In the shared application, they could see exactly what you are doing. When I move the mouse around and stuff... I move it to 14 minus 3 and they can see everything you do.*

This salience of task is also reflected in comments made by NetMeeting users in a field study of application sharing: they felt that using the shared application feature created the effect of being "on the same mental page" with remote meeting participants [19].

Motivation and Distraction

Two alternative explanations for our results are that subjects performed slower on math problems when observed because they were not motivated or perhaps because they were distracted. Questionnaire responses indicate that subjects' motivation did not differ significantly across conditions. We feel we can rule this out as an intervening variable. In interviews, subjects generally reported their motivation was unaltered by the media:

> *"I was told to do as best as I could. I attempted to do my best in all tasks."*

We cannot, however rule out that subjects were distracted by the media. Findings reported in Table 3, question 1 indicate subjects were more distracted in the video and application sharing conditions compared to the alone condition. While it is expected that some degree of visual distraction would arise from the video image, it is unclear why subjects would report being distracted in the application sharing condition since there was no difference in visually perceptible activity in this condition compared to the alone condition. Thus, we do not deny that distraction may have contributed to the performance effects we report here. However, we interpret the distraction to be a "mental' rather than visual distraction, in the same way that the presence of another person behind our back might mentally distract us.

Evaluation Apprehension

Another plausible explanation for our findings is evaluation apprehension. Evaluation apprehension is the fear of outcomes resulting when an individual's performance is critically examined by others. It is possible that evaluation apprehension contributed to the strength of the effects we report here. However, we do not believe it significantly threatens the generalizability of our findings because we believe evaluation apprehension is inherent to collaboration in the workplace when application sharing or video conferencing technology is used. In these contexts, an individual's competency is signaled by his or her performance on cognitive reasoning tasks. Furthermore, although virtually impossible to eliminate the effects of evaluation from an experiment which includes active monitoring by an observer [4], interview data suggest the effects of evaluation apprehension were minimal, e.g.:

"*I'm not afraid of being observed. I'm just going to let them observe me.*"

"*I was aware of the person but I didn't find it annoying.*"

Social Facilitation

Guided by the social presence paradigm, we have used our questionnaire data to explore affective responses to technology. Yet, because our research interest lies not only in affective responses to media but also productivity, we have also examined performance effects. Performance effects associated with the presence of another are often interpreted using the social facilitation paradigm. In the abstract, social facilitation refers to a change in performance, either a facilitation or impairment, resulting from the *physical* presence of others [27]. The social facilitation framework has been applied to study the effects of electronic performance monitoring on work [2,1]. These studies indicate that electronic monitoring worsens performance of complex tasks. Our findings are consistent with the social facilitation framework to the extent that we found significant performance impairment in the 'observed' conditions on complex tasks. Furthermore, we have extended the social facilitation framework by showing that the *electronic* presence of others causes task performance to deteriorate.

6. Limitations and Generalizability

There are a few important limitations to our study. First, we cannot rule out the effects of audio. We maintained an open audio connection in both the video conferencing and application sharing conditions because removing it would fail to simulate real-world collaboration. It is not expected that people would share applications or use video conferencing without an audio connection. Based on our subjects' interview responses, we are overwhelmingly convinced that video and application sharing contributed to the performance deterioration in math. However, further research would be necessary to investigate the extent to which audio was an intervening variable.

Another limitation is that we used only one observer. The observer in our experiment was a female. Whether we would have observed a different effect with a male or with a larger group of observers remains to be discovered.

And lastly, we cannot say to what extent our findings would hold for long-term use of media. On the one hand, we might expect people to acclimate to media use. On the other hand, since social presence concerns basic processes such as self-evaluation and impression management, they may in fact endure. As computer science majors, our subjects were highly skilled with computers, and many of our subjects were not unfamiliar with video conferencing and shared applications. Despite this, we still found effects. This suggests to us that our results lie not in the unfamiliarity with the technology, but rather in the social effects that the media facilitates.

To which settings could we generalize our findings? In many organizations, video conferencing and application sharing are used for ad-hoc interactions. Another common use is for supporting distributed teams who meet in real-time, but intermittently. We feel we can generalize our results to these settings. As mentioned earlier in the paper, in field studies we have seen how users in real work settings become extremely conscious of their screen actions with application sharing because their actions are highly visible to all team members.

And lastly, we feel that our results have strong implications for design and deployment of awareness mechanisms. Our findings suggest that if a user believes an awareness mechanism is displaying their face or computer screen to an unseen individual, their performance on cognitive tasks may be impaired. Furthermore, even when designs of such mechanisms afford reciprocal monitoring, as is the case in two-way video, electronic observation may still result in impaired performance.

7. Conclusions and Implications

Our findings indicate that a low-bandwidth connection such as application sharing can communicate the presence of another person. And, this sense of presence can be powerful enough to impact performance on a cognitive reasoning task. More specifically, when application sharing is used, a person's presence is salient even when visible cues are not available to indicate their presence. We also found that for a cognitive reasoning task, media use heightens the perception of task difficulty.

What implications can we draw from these results for the design and use of desktop conferencing systems and media spaces? First, our findings confirm those of others who claim that video provides a rich set of information about the affective response of others [15, 20]. However, where others have found that the overall quality of a collaborative product may improve with video and electronic conferencing [21, 20], our findings suggest that individual performance may suffer. Considering the tension between individual and group productivity, we suggest that when performance and quality are paramount, it is better to allow users to suspend the media connection periodically during collaborative work sessions. In other words, a continually 'open' communication channel via application sharing or video may be a detriment to performance.

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