AWARENESS DISPLAYS AND INTERRUPTION IN TEAMS

LAURA DABBISH, ROBERT KRAUT
Carnegie Mellon University
Human-Computer Interaction Institute
5000 Forbes Ave.
Pittsburgh, PA 15213 USA
Tel: (412) 268-7418
Fax: (412) 268-3620
email: {dabbish, kraut}@cs.cmu.edu

AWARENESS DISPLAYS AND INTERRUPTION IN TEAMS

ABSTRACT

Work life is filled with interruptions, most of which benefit the interrupter at the expense of the one being interrupted. We conducted an experiment to determine whether peripheral awareness information about a remote collaborator's workload aids in timing interruptive communication. Results indicate motivation to use the display exists, irrespective of whether both parties are rewarded as part of a team or not. When an informational display was present, a majority of participants used it to time their communication sensitively. We found that a display with an abstract representation of a collaborator's workload is best; it leads to better timing of interruptions without overwhelming the interrupter.

Keywords

Electronic communication, virtual work, interruption, awareness, computer mediated communication, computer supported cooperative work, instant messaging

INTRODUCTION

A hallmark of modern managerial and professional work is that it is communication intensive (Panko, 1992). Managers and professionals have multiple, spontaneous communications with multiple partners over the course of a single work day, to scan their environment, to exchange information, to influence, or request or provide advice (Reder and Schwab, 1988). Modern technologies, including electronic mail, instant messaging, pagers, wireless email devices, and cell phones, have made communication more convenient in more locations. Many observers consider the informal, spontaneous, and generally face-to-face communication pattern of managers and professionals highly functional, because it provides these workers fresh, rich information, which they need in order to do their jobs (Mintzberg, 1997). This functional view of workplace communication has dominated research within CHI and CSCW. In the early 1990s, for example, the goal of many research projects was to extend the benefits of spontaneous communication, which happens naturally in collocated settings, to distributed work groups (Abel, 1990; Dourish and Bly, 1992; Fish, Kraut et al., 1993; Tang, Isaacs et al., 1994; Whittaker, Frohlich et al., 1994).

However, informal, spontaneous communication comes at a cost: interruption. Managers think through important issues in three minute blocks of time because of interruptions (Sproull, 1984; Reder and Schwab, 1990). Perlow's (Perlow, 1999) fieldwork among engineers at a software company illustrates the trade-offs involved in spontaneous communication. When engineers needed help on a task, they would grab the person in the next office. This would disrupt the helper's own efforts and set them behind, in turn motivating them to grab the first person they could find when they needed help. Tetard's empirical research (1999) demonstrates that interruptions disrupt ongoing thought and O'Connaill and Frohlich's research (1995) shows that managers fail to return to the activity that was interrupted almost 50% of the time. This problem of disruption is compounded because of the unequal benefit that the interrupter and the interrupted party receive. Both O'Connaill and Frohlich (1995) and Kraut and Attewell (1997) demonstrate that for interruptions between human coworkers, the interrupter gains most from the interruption.

CONTROLLING INTERRUPTIONS

Three generic techniques have been applied to control the disruption associated with spontaneous interaction: (1) providing the target of the interruption with filtering and other technologies to control to the volume and nature of incoming communication; (2) manipulating economic and other incentives of the interrupters in order to reduce the volume of communication they send and increase their selectivity; and (3) imposing norms or providing information displays to synchronize interruption attempts with periods when the target is not intensively engaged in some task.

Email filters, answering machines, and more sophisticated technologies (Horvitz, Jacobs et al., 1999) are attempts to increase the control that a target of an interruption has over incoming traffic. While granting control to the target is likely to help conserve the target's attention, it does not honor the often-legitimate needs that the interrupter has for the target's time and attention. Targets (or their software surrogates) are forced to make decisions about communication based on one-sided information. They know how busy they are, but don't know the urgency or importance of the incoming communication.

This one-sided decision process can undercut cooperation, which is so important in organizational life. McFarlane's study on interruption (McFarlane, 1999) illustrates the problem. Participants played a Jumpers

Game as their primary task. This is a video game in which they save on-screen icons jumping from a building. They were periodically interrupted from the Jumpers Game by a secondary matching task. Subjects who were interrupted performed more poorly on their primary task than those who were not. Their performance improved when they were allowed to control the timing of the interruptions. However, when granted control, they delayed attending to and failed to respond to a portion of the interruptions. Had these interrupts come from another member of the organization, many important questions or messages would not have gotten through.

With economic incentive schemes (e.g., variable rate postage), communicators, who know the importance and urgency of their messages, pay for those they believe to be most important. According to both theoretical modeling (Zandt, 2001, May 18) and empirical evidence (Kraut, Sunder et al., 2003), economic incentive schemes cause potential interrupters to communicate more selectively. Thus targets are less likely to be interrupted by irrelevant communication, such as spam. However, these schemes face the practical impediment of introducing charges for what is currently a free service.

Mechanisms for synchronization, which deliver communication when targets are least busy, can improve productivity and help interrupters without harming communication targets. Perlow, in her study of software engineers, conducted a field experiment, in which certain times of the day were designated for individual work (when people couldn't interrupt), and other times for interactive work (when people could interrupt each other). This synchronization mechanism had positive effects on productivity (Perlow, 1999). While both engineers and their managers appreciated this regime of quiet times and busy times, they were not able to maintain it. After the study was over, when Perlow was no longer available to enforce the norm, the engineering firm reverted to its highly interactive, highly interruptive, crisis-driven pattern of communication. This backsliding may have happened because the synchronization attempt occurred at too global a level. It required all engineers in a unit to postpone their interaction to the interactive period, even if one had an urgent question and a potential advisor had free time.

Other researchers have attempted to build displays that show potential interrupters the attentional states of their targets. These displays could in principle allow individual communicators to time their interruptions during the targets' idle states. For example, Hudson (Hudson and Smith, 1996) built visual indicators to show whether someone was talking to someone else, while not revealing the other's identity. Other examples of these kinds of awareness displays that make visible the actions of others include: (Cadiz, 2002; Isaacs, 2002; Nichols, 2002). The notion that the visibility of others actions is useful for coordinating joint activity has been discussed in previous literature on designing computer systems for distributed collaborative work (Malone, 1987). However, there is as yet no evidence that the awareness displays developed thus far help to synchronize the joint activity of communication. Indeed the major conclusion one can draw from much CSCW work of the 1990s is that displays that show someone's availability increase communication, rather than regulate it. Thus we aim to address an important question with implications for the value of awareness displays: does providing visibility of a co-worker's actions through an awareness display aid in synchronizing communication?

AN EXPERIMENT TO ASSESS THE VALUE OF AWARENESS DISPLAYS

In the work presented in this paper we attempt to address the interruption problems outlined above. Previous work shows that there are appropriate times in a task where disruption from interruption can be minimized. Cutrell et al.'s research (E. Cutrell, 2001) indicates interruptions can be timed so that they are less disruptive. In their study, experimenters interrupted participants with instant messaging during various points when they were searching a list. Disruption caused by an interruption was minimized if the interruption was delivered towards the end of the search task rather than towards the beginning.

The implication of this research is that given the correct information, a co-worker can appropriately time interruptions, obtaining the information they need while minimizing the disruption their target experiences (Teasley, 2000). With appropriate motivation, they may use this information to improve synchronization of their interruption attempts and ongoing tasks.

Research Questions and Hypotheses

There are several tradeoffs involved in the timing communication in collaborative work. For ease of discussion, let us consider the abstract situation as depicted in Figure 1.

Insert Figure 1 about here

Here we have two parties collaborating. On one side is an Asker who needs information, and on the other side is a Helper–an expert with the information that the Asker needs—(this needs to be a double dash) who is working on another task. The Asker wants to send the Helper an interrupting query. However there are two conflicts.

First there is the synchronization problem. The Asker should send the query so that it reaches the Helper at a time when the Helper is available (i.e., not engaged in a higher priority task). To synchronize the request with availability, the Asker needs some feedback about the Helper's task and attentional status. When collaborators are co-located, this kind of feedback can be obtained through observation of cues such as door status (Nichols, 2002), posture, whether the person is on the phone, etc. However when collaborators are distributed this kind of feedback is not typically available. We believe providing relevant information to these remote collaborators will help them to better time their interruptions.

Hypothesis 1: A display with information about a collaborator's workload will increase joint performance, improving a help-seeker's performance while minimizing disruption of the help-giver's performance.

The nature of the informational display is important. In particular the amount of information that the Askers could receive about Helpers' attentional state could make a great difference in their ability to time interruptions. A display with insufficient information would harm the Helper, because the Asker would make poor decisions about when to interrupt. On the other hand, displays with high informational content could benefit the Helper, because the Asker could time interruptions at a period of idleness. CSCW systems of the 1990s, which delivered full video of a collaborator's office, provided this level of information (E.g., Fish, Kraut et al., 1993; Tang, Isaacs et al., 1994).

At the same time, this informative display continually providing the Helper's task state could hurt the Asker, because it places high demands on the amount of attention required to process and use the information it presents. To balance the trade-off between information presented and attention required, an abstract display that contains only the essential information about the Helper in an easy to understand form could be preferable.

Hypothesis 2: There will be a curvilinear relationship between the detail in an awareness display and joint performance. Both too much and too little detail will harm joint performance.

Hypothesis 2a: Providing too little information about the Helper's state would harm the Helper's performance.

Hypothesis 2b: Providing too much information about the Helper's state would harm the Asker's performance.

The second problem with interruptions is an inherent value conflict problem between the two parties. The Helper's time is not worth as much to the Asker as the information that the Helper could provide. When the Asker has no stake in the Helper's performance the Asker has no motivation to time interruptions so that they are convenient for the Helper. Thus, without appropriate motivation, information displays may be irrelevant.

One solution is offered in the social psychology literature on self-managing teams. In these self-managing teams, team members are rewarded based on the team's overall performance, not on their individual performance. Having a common team identity and combined team rewards encourages members of these teams to be more cogniscent of the activities of their peers and strive for the welfare of the group as a whole (E.g., van der Vegt, Emans et al., 1998). Thus our third hypothesis is:

> **Hypothesis 3:** Being part of a team with joint rewards will increase the effectiveness of awareness displays on joint outcomes.

To test these hypotheses, we designed and performed a controlled experiment described in the next section. The laboratory setting allowed us to independently assess the impact of a workload display on remote collaborators' performance.

Method

Our experiment was designed to test our hypotheses using a stylized version of the situation described by Perlow (Perlow, 1999). Our task was a 2-player game where players were interdependent: one player depended upon the other one for help. The Asker's primary task was a game in which they had four minutes to guess the contents of a partially obscured image being slowly revealed to them (see Figure 2). Small black squares covering the image were gradually removed over the four minutes, while random larger squares of the picture were revealed and then hidden again. The Askers' performance would improve if they watched the larger squares.

Insert Figure 2 about here

The other player, known as the Helper, had the Jumpers video game used by McFarlane (McFarlane, 1999) as a primary task. In this game, they had to save people jumping from a building by moving corpsmen with a stretcher underneath them. At random intervals, the program launched a new jumper. At any moment, the Helpers had between zero and nine jumpers that they were trying to rescue.

The Helper also had on their screen the image that the Asker was trying to guess, and thus became an expert with the information that Asker needed (see Figure 3). The Asker, seated in a separate room, was able to send the Helper 20 questions over the computer, which could be answered either 'yes' or 'no' about the picture they were attempting to guess. The questions, when delivered to the Helper, took over the screen until they were answered.

We manipulated both the interdependence of the pair's rewards and the information the Asker had about the Helper's workload (the number of jumpers that needed to be saved). We analyzed the rate and timing of the Asker's questions, and their effect on both players' performances.

Insert Figure 3 about here

Awareness display. The game consisted of three rounds, during each of which the Asker had to guess the identity of four different pictures. To test our first hypotheses regarding the role of awareness information in timing interruption, we manipulated within subjects the amount of information that the Asker received about the state of the Helper's task. Because an interruption would be more disruptive when more jumpers were on screen, we varied the information about jumpers that the Asker received.

Insert Figure 4 about here

In the *full display condition,* Askers saw a 2.5” x 2.5”, real-time replicate of the Helper’s screen, implemented as a Virtual Network Computing (VNC) window on their computer. In the *abstract display condition*, they saw icons representing the number of Jumper’s on the Helper’s screen. Finally, in the *none display condition,* they received no information about the Helper’s current task. Figure 4 shows each of the three displays. Each subject saw each of the three awareness display conditions during one round of the game; display order was counter-balanced using a Latin square design.

Team orientation. To test the second hypotheses about motivation to interrupt sensitively, we manipulated between subjects whether the Askers were independent or part of a team. In the independent condition participants in the Asker role were rewarded based on their individual performance, were told they were competing with the Helper for a fifty dollar prize, and wore a jersey of a different color than the Helpers’. In contrast, in the team condition Askers were told they were on a team with the Helper, they were rewarded based on the average of their score and the Helper’s score, they were competing as a team against other teams for the fifty-dollar prize; they and the Helpers wore matching jerseys.

It is important to note that in both the *independent* and *team* conditions, Helpers were informed that they were on a team with the other player. This was done to control for any affect of team membership on the Helpers’ performance in answering questions from the Asker. The Helpers’ goal was to equally weight the importance of the Jumpers game task and the importance of the incoming questions from their partner.

Participants. Thirty-six Asker-Helper pairs (72 individuals) took part in the experiment. Participants were recruited from local universities. The mean age for participants was 22.9 years of age (std. dev. = 5). Participants were of above average intelligence, with the mean SAT scores being 682 for math (std. dev. =

85.2) and 671 for verbal (std. dev. = 65.3). Participants' standardized GPA score out of 100, was 81 (std. dev. = 16).

RESULTS

A pair's performance on an individual picture was the unit of analysis. The number of pictures analyzed was 432 (36 pairs X 3 display conditions X 4 pictures per display). Because pictures were nested within display condition and pairs, they were not independent. Therefore they were analyzed using a repeated measure mixed-model analysis of variance.

We obtained effects for performance differences between conditions which supported our first two hypotheses, and larger effects for differences in question timing and question rate behaviors. Overall we found that over 60% of participants were using information about the Helper, when it was available, to time their interruptions.

Performance Results

Helper. The Helper's performance was measured by the percent of jumpers saved during each picture. Consistent with Hypothesis 2a, the Helper was able to save approximately 7% more jumpers in the full display and abstract display conditions than in the no display condition ($F(1,388)=5.52$; $p < 0.02$). The means for each condition were: None M = 70.68%, Abstract M = 75.04%, Full M = 74.63% with pooled standard error of 1.85%. The overall effect of display was marginally significant, where $p = 0.06$ ($F(2,388)=2.78$). This suggests that simply providing information about a remote partner results in more sensitive question timing, and thus an increase in the remote partner's performance.

Asker. The Asker's performance was measured by the accuracy in their identification of the pictures and the time, in seconds, it took them to identify each picture. There was no effect of the awareness display condition on the Asker's accuracy at identifying pictures (F(2,388)=0.15, p=0.86; mean accuracy = 79%). There was no overall main effect of the awareness display condition on the time it took Askers to identify the pictures (F(2,388)=2.16, p=0.11). However, in planned comparison of time to identify for each condition, a significant difference was observed between the full condition and the other two conditions (abstract and none). Consistent with Hypothesis 2b, Askers took 12.5% longer to guess pictures in full information condition versus the abstract information condition or no information condition (F(1,388)=3.98, p<0.05). The abstract and no display conditions did not differ from each other. The means for each condition were: None M = 110sec, Abstract M = 105 sec, Full M = 121 sec with pooled standard error of 7.58 sec.

Joint performance. Because Askers had best performance in the abstract and no display condition, and Helpers had best performance in the full and abstract display conditions, joint performance was best in the abstract display condition. This result is consistent with Hypothesis 2b, that an abundance of information in the display would harm the Asker's performance. Performance results for the Asker and Helper in each display condition, considered across team orientation are summarized in Table 1 below.

Insert Table 1 about here

There was no main effect of team orientation on performance for the Asker (F(1,34)=0.38; p=0.54) or performance for the Helper (F(1,34)=0.02; p=0.89), and no effect of the interaction of team orientation with awareness display on performance for the Asker (F(2,388)=1.08; p=0.34), or Helper (F(2,388)=0.78; p=0.46). Thus, we did not find support for Hypothesis 3. There are several possible reasons we can cite for this result, described in the discussion section below.

Interruption Behavior

To examine the mechanisms through which these performance differences occurred, we looked at the effects of the team and display conditions on interruption behavior. These results are summarized in Table 2.

Insert Table 2 about here

Question timing. To examine whether the display conditions influenced the synchronization of interruptions with periods of low workload, we measured the number of jumpers on screen when each question from the Asker was sent to the Helper. As can be seen in Figure 5 below, Asker participants were 43% less likely ($F(2,382)=18.76$; $p < 0.0001$) to send a question when there were jumpers on the screen during the conditions where they had information about the Helper (the abstract and full conditions). Thus both informative displays improved synchronization. The means for each condition were: None M = 75.4%, Abstract M = 43.3%, Full M = 42.3%, with pooled standard error of 5.2%. There was no effect of team orientation on question timing ($F(1,34)=0.066$; $p=0.79$), and inconsistent with Hypothesis 3, no effect of the interaction between team orientation and display condition ($F(2,382)=2.21$; $p=0.11$).

Insert Figure 5 about here

We also collected qualitative data about question timing. Following each round participants were given a questionnaire about their experiences during the round. Askers described their strategy for deciding when to send questions to the Helper. In the *Abstract* information condition 60.8% of participants reported using the display in deciding when to send questions to their partner. Because the only information the Asker received during this condition was number of jumpers, all of these strategies involved sending questions when this number was below some threshold. For example, Askers offered the following descriptions of their strategies in the abstract display condition:

- When there was only 1 person on the jumper indicator
- When there was one jumper. I tried to ask as few questions as possible and to figure out the picture on my own.
- When there were 2 or less jumpers

For the *full* information condition, 66.6% of participants reported using the display to determine when to send questions to their partner. The strategies participants described during the *full* condition were more complex than those described during the *abstract* information condition, involving not only the number of jumpers but more detailed information about the task state. For example, Helpers described their strategies as follows:

- I waited until there were 1 or fewer jumpers on the screen and if the current position of the net was okay or had to be moved soon.
- Whenever she had people at the apex of their bounce or if there was a break in the jumpers
- Tried to do it when the people where higher in the air so they had time to answer without loosing a person

These qualitative results suggest that providing information about a remote partner does indeed have an effect on interruptive behavior. In this case, the more information that was provided, the less frequently participants sent interruptions, and the more carefully they timed each interruption they sent.

Question rate. The number of questions sent during each picture was used to calculate the Asker's question rate, or average number of questions sent per minute. Question rate significantly decreased as information about the other player increased ($F(2,388)=10.40$, $p<.0001$). Questions per minute decreased by

7% from no information condition (None M = 2.77) to abstract information condition (Abstract M = 2.57), and by 14% from abstract information condition to full information condition (Full M = 2.23).

Askers asked 34% fewer questions per minute in the team condition (M = 2.00) than the individual condition (M = 3.05) where $F(1,34)=10.03$, $p<0.003$. There was no effect of the interaction between team orientation and awareness display on question rate ($F(2,388)= 0.067$, $p = 0.94$).

User satisfaction. We were interested in the participants' preferences for the different awareness displays. Upon completing the experiment, participants filled out a questionnaire about their experience. Participants in the role of Asker were asked to rank order the displays that they had seen, in terms of their preference for each. 63.8% of subjects ranked the display with full information about their partner as the one they most preferred. The abstract display with information about their partner (number of jumpers) was ranked by 72.2% of participants as their second most preferred. Finally the display with no information was ranked by 72.2% of participants as the least preferred.

DISCUSSION

Awareness Displays

In our experiment, the highest joint performance occurred during the abstract display condition, the condition where the Asker saw a display with an abstraction of the Helper's current workload. In this condition the Helper saved the most jumpers, and the Asker completed their task most efficiently. This result provides support for our Hypothesis 1, that an informational display would increase joint performance.

What caused these performance differences between display conditions? As we noted in the results above, the Asker reduced their question rate from the no information condition to the abstract information condition, and from the abstract condition to the full condition. However, simply reducing the interruption rate did not result in a performance increase for the Helper. Rather, the timing of the interrupts is also important.

Askers in the team condition also significantly reduced their interruption rate, but Helpers in the team condition did not perform better than Helpers in the independent condition. This suggests that the improvements in the Helper's performance in the informative display conditions resulted from the Askers' greater ability to time interruptions during these conditions so they arrived during periods of low workload for the Helper. This corresponds with the results examining the timing of interruptions, showing that the Askers were significantly less likely to send questions when there were jumpers on the Helper's screen during the informative conditions. Askers were strategically timing their questions by using information from the displays during the information conditions. Askers' self-reports of their strategies, showing that over 60% of Askers reported using the display to time their questions, are also consistent with this interpretation.

Thus we find support for Hypothesis 1, that a display with information increased joint performance. However, the display did not provide unalloyed benefit. Recall that Askers took longest to guess pictures during the full information condition. There are two probable contributors to this result. The first relates to attention. It is possible that during the Full condition, the feedback display showing the Helper's entire game placed a large burden on the Asker's attentional resources. They may have had difficulty dividing their attention between the picture being revealed and the feedback display showing the Helper's game in the corner of their screen. In addition a great deal of attention may have been required to utilize the information in the full display.

Another contributor to this result is that Askers in the full display condition were using information from the display to time their interrupts in a more subtle way than Askers in the abstract display condition. This idea is supported by the reduction in question rate during the full information condition, and by our qualitative questionnaires following each round. Thus, because the Asker was given such specific information about the other player's game during the full condition, it seems they "overtimed" their questions so much that they took significantly longer to solve their pictures without benefiting the Helper. To decide when to send questions during the full condition, the Asker waited and watched for specific situations in the Helper's game rather than using a simple heuristic involving the number of jumpers on the Helper's screen.

By looking at the performance for the Helper, we can see that the added deliberation in timing during the full condition did not translate into additional performance increases for the Helper during the full condition. Our results indicate that the more information provided to the Asker about the Helper's task, the more the Asker modified their behavior. The Asker sent questions least frequently and took longer to identify pictures in the condition where they had full information about the Helper. This supports Hypothesis 2 (both parts 2a and 2b) regarding the curvilinear relationship between performance and information: too little information hurt the Helper's performance, while too much information hurt the Asker and did not provide additional benefits for the Helper. Thus an abstract display with an intermediate amount of information balances both the Asker and Helper's needs. Table 3 provides a summary of our hypotheses and related results providing support for several of them.

Insert Table 3 about here

Motivation to Interrupt Sensitively

Surprisingly, there was no influence of team orientation on either Helpers' or Askers' performance and on question timing, and no interaction of team orientation with display condition for any of the measures we looked at. Thus, the experiment provides no support for Hypothesis 3. This would seem to suggest that being part of a team did not sufficiently motivate participants to interrupt more sensitively. Rather, we believe our results imply that simply providing the Asker with information about the Helper's task is sufficient motivation for the Asker to time their interruptions more sensitively. Perhaps providing additional motivation is unnecessary, and it is enough to simply make a potential interrupter more aware of a recipient's constraints in order to encourage appropriate interruption timing.

It is possible, however, that our experimental manipulations did not sufficiently differentiate the team condition from the independent one. In particular, various conditions of the experiment may have made Askers in the independent condition empathize with the Helpers. Participants in a pair were similar in age, student status, and had met each other at the beginning of the experiment, all of which can lead to liking (Cialdini, 1993). In addition, norms of reciprocity (Gouldner, 1960) may have also caused Askers to attempt to aid the Helpers. It is not clear that without these mitigating circumstances, potential interrupters would be motivated to time their communication to minimize costs to their targets. It is hard to imagine, for example, that telemarketers would benignly use information about whether someone was at dinner.

FUTURE WORK

One of the biggest challenges with laboratory experiments using highly stylized tasks, such as the one described here, is ensuring the results generalize. In our case we must investigate whether these results generalize to other types of tasks. It will be interesting to see if the same kinds of differences occur with more complex tasks, such as the daily tasks of a knowledge worker. To investigate this we would like to carry out additional experiments with different kinds of tasks for participants in both the Asker and Helper roles.

We must also consider the temporal nature of different tasks, and the granularity of the abstract information we would provide in each case. In our experiment using the Jumpers task, the state of the game was changing every second, so the kind of full information display, with constant update, made sense. During the Jumpers task there are periods of low workload every ten to thirty seconds. But as previous work on interruption shows, appropriate times for interruption in other tasks can be fewer and much farther apart. For example a recent study of IBM managers' interruptibility throughout the day (Hudson, 2002) found that managers were more interruptible at certain times of the day, so their state changed every several hours, a much larger time scale

Another big issue in applying this work is how to generate the kind of abstract informational display used in the experiment for different kinds of tasks. Here availability or busyness may not translate easily into something directly measurable. In these cases we can turn to techniques being developed such as the Priorities system (Horvitz, Jacobs et al., 1999), which utilizes sensing technologies and machine learning algorithms to assess an individual's level of occupation. These assessments could become input used to generate displays with an abstract representation of someone's activity level or current workload. We hope to experiment with one or two physiological sensors, such as heart rate or galvanic skin response (GSR), to see how these inputs correspond with someone's level of occupation.

CONCLUSION

Interdependence exists between both parties in an interrupter-target dyad. There is a design trade-off between what is best for the interrupter (no information in a display) and what is best for the target (a display with perfect information). We have shown that a balance can be met in the form of a display for the interrupter presenting an abstract representation of key information about the target.

Although we performed our experiment in the laboratory, we believe these results apply more generally to natural settings similar in nature to our experimental paradigm. Particularly these resuls are of use in developing awareness displays for tasks that require continuous attention, where change in the environment is frequent, and communication with coworkers is important. For example, bond traders such as those studied by Heath et al. (Heath, Jirotka et al., 1995) exhibit both of these characteristics in that they must be continuously watching the market for changes but at the same time need to coordinate with their team members on the floor to ensure their actions are aligned while trading.

From our results, we can make a clear recommendation for designing awareness displays for these settings. Primarily, the right amount of feedback about a remote collaborator is helpful to joint performance and can aid interruption timing. These results are helpful in illustrating that more information in a display about a remote collaborator isn't necessarily better. It can actually be distracting and harmful to the productivity of the person using the display, to say nothing of the privacy issues it raises.

ACKNOWLEDGMENTS

We would like to thank Daniel McFarlane for his input and for the use of his Jumpers game task. We would also like to thank Matthew Hockenberry for his involvement in implementing and deploying the experiment, and Darren Gergle for his helpful advice on analysis.

REFERENCES

Abel, M. J. (1990). Experiences in an exploratory distributed organization. Intellectual teamwork: Social and technological foundations of group work. J. Galegher, R. Kraut and C. Egido. Hillsdale, NJ, Lawrence Earlbaum Associates**:** 489-510.

Cadiz, J. J., Venolia, G.D., Jancke, G., & Gupta, A. (2002). Designing and Deploying an Information Awareness Interface. Proceedings of the 2002 Conference on Computer Supported Cooperative Work, ACM Press.

Cialdini, R. B. (1993). Influence: Science and practice. New York, NY, US, HarperCollins College Publishers.

Dourish, P. and S. Bly (1992). Portholes: Supporting awareness in a distributed work group. Proceedings of CHI92 : Human Factors in Computing Systems. New York, ACM**:** 541-547.

E. Cutrell, M. C., & E. Horvitz (2001). Notification, Disruption, and Memory: Effects of Messaging Interruptions on Memory and Performance. Human-Computer Interaction--Interact '01, Tokyo, Japan, IOS Press.

Fish, R. S., R. E. Kraut, et al. (1993). "Evaluating video as a technology for informal communication." Communications of the ACM **36**(1): 48-61.

Gouldner, A. W. (1960). "The Norm of Reciprocity: A Preliminary Statement."American Sociological Review **25**: 161-178.

Heath, C. G., Rich., M. Jirotka, et al. (1995). "Unpacking Collaboration: The Interactional Organisation of Trading in a City Dealing Room." Computer Supported Cooperativge Work **3**(2): 147-165.

Horvitz, E., A. Jacobs, et al. (1999). Attention-Sensitive Alerting. UAI '99, Conference on Uncertainty and Articial Intelligence, Stockholm, Sweden, Morgan Kaufmann.

Hudson, J. M., Christensen, J., Kellog, W.A., & Erickson, T. (2002). "I'd be overwhelmed, but its just one more thing to do": availability and interruption in research management. CHI2002 : Human Factors in Computing Systems, Minneapolis, MN, ACM.

Hudson, S. and I. Smith (1996). Techniques for Addressing Fundamental Privacy and Disruption Tradeoffs in Awareness Support. Proceedings of the 1997 SIGCHI Conference. New York, ACM Press**:** 248-257.

Isaacs, E., Walendowski, A., & Ranganathan, D. (2002). Hubbub: A sound-enhanced mobile instant messenger that supports awareness and opportunistic interactions. roceedings of the Conference on Computer-Human Interaction (CHI) '02, ACM Press.

Kraut, R. E. and P. Attewell (1997). Media use in a global corporation: Electronic mail and organizational knowledge. Culture of the Internet. S. K. (Ed.). Mahwah, NJ, Lawrence Erlbaum Associates**:** 323-342.

Kraut, R. E., S. Sunder, et al. (2003). Markets for Attention: Will Postage for Email Help? Proceeding, Computer Supported Cooperative Work. New York, Association of Computing Machinery.

Malone, T. W., Ken R. Grant, Franklyn A. Turbak, Stephen A. Brobst, and Michael D. Cohen. (1987). "Intelligent Information Sharing Systems." Communications of the ACM **30**: 390-402.

McFarlane, D. C. (1999). Coordinating the Interruption of People in Human-Computer Interaction. Proceedings of Human-Computer Interaction (INTERACT'99), IOS Press.

Mintzberg, H. (1997). The manager's job: Folklore and fact. Leadership: Understanding the dynamics of power and influence in organizations. R. P. Vecchio. Notre Dame, IN, US, University of Notre Dame Press**:** 35-53.

Nichols, J., Wobbrock, J.O., Gergle, D., and Forlizzi, J. (2002). Mediator and Medium: Doors as Interruption Gateways and Aesthetic Displays. *Proceedings of DIS'2002*, London, UK.

O'Conaill, B. and D. Frohlich (1995). Timespace in the workplace: Dealing with interruptions. Proceedings, Conference Companion, Human Factors in Computing Systems. New York, ACM Press**:** 262-263.

Panko, R. R. (1992). "Managerial communication patterns." Journal of Organizational Computing. **2**: 95-122.

Perlow, L. A. (1999). "The time famine: Toward a sociology of work time." Administrative Science Quarterly **44**(1): 57-81.

Reder, S. and R. G. Schwab (1988). The communicative economy of the workgroup: multi-channel genres of communication. Proceedings of the conference on Computer-supported cooperative work. New York, ACM Press**:** 354 - 368.

Reder, S. and R. G. Schwab (1990). "The temporal structure of cooperative activity." Proceedings of the conference on Computer-supported cooperative work, 1990: 303 - 316.

Sproull, L. (1984). The nature of managerial attention. Advances in Information Processing in Organizations. L. Sproull and J. Larkey. New York, JAI Press**:** 9-27.

Tang, J. C., E. A. Isaacs, et al. (1994). Supporting Distributed Groups with a Montage of Lightweight Interactions. Proceeding of the Conference on Computer Supported Cooperative Work. New York, ACM Press**:** 23-34.

Teasley, S., Covi, L., Krishnan, M.S., & Olson, J.S. (2000). How does radical collocation help a team succeed? *Proceedings of the Conference on Computer-supported Cooperative Work*, ACM Press.

Tetard, F. (1999). On Fragmentation of Working Time: a Study of Causes and Effects on Work Interruptions, Institute for Advanced Management Systems Research.

van der Vegt, G., B. Emans, et al. (1998). "Motivating effects of task and outcome interdependence in work teams." Group & Organization Management **23**(2): 124-143.

Whittaker, S., D. Frohlich, et al. (1994). Informal workplace communication: what is it like and how might we support it? Conference proceedings on Human factors in computing systems : “celebrating interdependence”: “celebrating interdependence”. New York, ACM Press**:** 131 - 137.

Zandt, v. T. (2001, May 18). Information overload in a network of targeted communication.

FIGURES AND TABLES

TABLE 1

Performance results across team conditions

		Display Condition			Statistics		
		(None)	**(Abstract)**	**(Full)**	**Difference?**	**F**	**p**
P(A)*	**Accuracy (prob)**	M=0.79 SE=0.04	M=0.80 SE=0.04	M=0.78 SE=0.04	No	0.16	0.86
	Time (sec)	M=110 SE=7.60	M=105 SE=7.60	M=121 SE=7.60	No (overall effect) Significant in planned comparison Full vs None+Abs (F=3.98, p=0.05)	2.16, 3.98	0.12, 0.05
P(H)**	**% jumpers saved**	M=70.68 SE=1.90	M=75.04 SE=1.80	M=74.60 SE=1.90	Marginal (overall effect) Significant in planned comparison None vs Abs+Full (F=5.51, p=0.02)	2.78, 5.51	0.06, 0.02
	Extra Keys	M=4.18 SE=1.27	M=4.26 SE=1.27	M=4.56 SE=1.27	No	0.08	0.93

* P(A) = Performance of Asker

**P(H) = Performance of Helper

TABLE 2

Interruption behavior of Asker across team conditions

	Display Condition			Statistics		
	None	**Abstract**	**Full**	**Difference?**	**F**	**p**
Num Questions	M=4.4 SE=0.34	M=4.15 SE=0.34	M=4.16 SE=0.34	No	0.421	0.657
Log (Question Rate)	M=0.045 SE=0.0029	M=0.042 SE=0.0029	M=0.037 SE=0.0029	Yes	10.30	<0.0001
Jumpers On Screen	M=0.754 SE=0.052	M=0.433 SE=0.052	M=0.423 SE=0.052	Yes	18.76	<0.0001
Used Display (7 point scale self-report response)	M=0.21 SE=0.062	M=0.57 SE=0.062	M=0.78 SE=0.062	Yes – Higher as information increased	13.82	<0.0001

TABLE 3

Summary of support for stated hypotheses (Summary of hypotheses and related results)

Hypothesis	**Supported?**	**Discussion of Results**
Hyp 1. Awareness display will increase joint performance	Yes	The Helper's performance was significantly better during conditions where the Asker had a display. The Asker's performance was worst during the full display condition. Thus the abstract display condition is optimal for joint rewards.
Hyp 2. A curvilinear relationship exists between detail in awareness display and performance.		
Hyp 2a. Too little information in the display will harm the Helper	Yes	The Helper's performance was significantly worse during the conditions where the Asker had no information about the Helper.
Hyp 2b. Too much information in display will harm the Asker	Yes	The Asker's performance was significantly worse in that they took longer to complete their task during the condition where they had full information about the Helper.
Hyp 3. Joint reward structure will increase utility of display	No	There were no significant performance differences for team members versus non-team. Team members sent less interruptions but did not time their interruptions more sensitively.

FIGURE 1

Interruption Situation in the Abstract

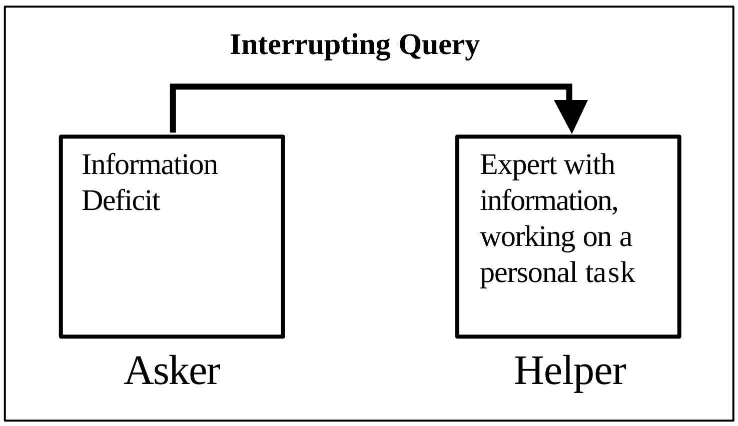

FIGURE 2

Asker's Screen in Experiment, with larger revealing square highlighted

FIGURE 3

Helper's Screen in Experiment

FIGURE 4

Awareness Display Conditions (counter clockwise from top left: *None*, *Abstract*, *Full*)

FIGURE 5

Probability of Asker sending a question when there were jumpers on the Helper's screen