Controlling Interruptions: Awareness Displays and Social Motivation for Coordination

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ABSTRACT

Spontaneous communication is common in the workplace but can be disruptive. Such communication usually benefits the initiator more than the target of the interruption. Previous research has indicated that awareness displays showing the workload of the target can reduce the harm interruptions inflict, but can increase the cognitive load on interrupters. This paper describes an experiment testing whether team membership influences interrupters' motivation to use awareness displays and whether the informational-intensity of the display influences their utility and cost. Results indicate interrupters use awareness displays to time communication only when they and their partners are rewarded as a team and that this timing so improved the target's performance on a continuous attention task. Eye-tracking data shows that monitoring an information-rich display imposed a substantial attentional cost on the interrupters, and that an abstract display provided similar benefit with less distraction.

Categories and Subject Descriptors

H.5.3 [**Information Interfaces And Presentation**]: Group and Organization Interfaces – *computer supported cooperative work, synchronous interaction*

General Terms

Performance, Design, Experimentation, Human Factors.

Keywords

Interruption, Awareness, Coordination, Attention, Social Identity, Gaze Tracking

1. INTRODUCTION

A hallmark of modern managerial and professional work is that it is communication intensive [22]. Managers and professionals have many spontaneous communications with multiple individuals over the course of a single work day in order to scan their environment, to exchange information, to influence, to request or provide advice [25]. Many observers consider the informal, spontaneous communication exchanged by managers and professionals highly functional, because it provides these workers with the fresh, rich information they need to do their jobs [20]. This functional view of workplace communication has dominated research within CHI and CSCW. In the early 1990s, for example, many research projects attempted to extend the benefits of spontaneous communication to distributed work groups [1, 4, 6, 28, 32].

Unfortunately, informal spontaneous communication comes at a cost-- interruption. Modern communication technologies, including electronic mail, instant messaging, pagers, wireless email devices, and cell phones, have made communication more convenient, but have also increased sources of interruption. Empirical research demonstrates the costs associated with interruptions in the workplace. For example, Perlow's [23] fieldwork demonstrates that software engineers exchange substantial help with co-workers, but that constant interruptions set back production schedules. (See also Tetard [30] and O'Connaill and Frohlich [21].) Because of interruptions, managers think through important issues in extremely short blocks of time [26, 27]. The generic problem of disruption is compounded because the interrupter and the target receive unequal benefits. Both O'Connaill and Frohlich [21] and Kraut and Attewell [16] demonstrate that the interrupter gains more from the interruption and incurs less cost.

Awareness displays are designed to encourage communication, while minimizing the disruption associated with interruption by displaying a target's current state. Displays revealing information about a potential communication partner can serve this function. For example, participants in field trials of media spaces often used full-frame, video images of other members of a workplace to time when to drop in on someone, so that they were available but not busy in a meeting or on the phone [1]. The minimalist availability displays (e.g. “away” messages) on many instant messaging systems serve the same function. Dabbish and Kraut [3] demonstrated in the lab that such displays can successfully coordinate communication and minimize the disruption associated with interruptions.

Many designers assume that that the mere presence of an awareness display will cause potential interrupters to regulate their communication based on the state of a potential target. However, we posit that such displays are only useful when an interrupter is motivated to be concerned about the disruption they may cause the target of an interruption. Even though a close friend might refrain from calling during dinner, the proverbial telemarketer will not.

In the empirical study described below, our goal is to understand the conditions under which awareness displays can successfully coordinate communication. The experiment varies the amount of information a display reveals about a target of communication and the communicator’s motivation to minimize disruptions.

2. CONTROLLING INTERRUPTIONS: PREVIOUS WORK

The dominant technique to control disruption has been to provide the target of the interruption with filtering technologies that control the volume and nature of incoming communication. Receptionists, mail filters, answering machines, and more sophisticated technologies [12] are attempts to increase the control that a target of 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 only on how busy they themselves are, without knowing the urgency or importance of the incoming communication.

This one-sided decision process can undercut cooperation, which is important in organizational life. McFarlane’s study on interruption [19] illustrates the problem. Participants played a Jumpers Game as their primary task. This is a video game in which the goal is to save virtual people jumping from a burning building. Participants were periodically interrupted from the Jumpers Game by a secondary matching task. Participants 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 they could control interruptions, they failed to respond to a large fraction of them. Had these interruptions come from another person, many messages the interrupter judged important would not have gotten through or would have been delayed.

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 [23]., described a field experiment in which the organization designated certain times of the day for individual work (when people couldn’t interrupt), and other times for interactive work (when people could interrupt). This synchronization mechanism had positive effects on productivity. While both engineers and their managers appreciated this regimen of quiet times and busy times, they were not able to maintain it. Eventually the engineering firm reverted to its highly interactive, highly interruptive, crisis-driven pattern of communication. This backsliding may have happened because the time-synchronization attempt occurred at too temporally gross a level. It required all engineers in a unit to postpone their communications until 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 allow individual communicators to time interruptions during the targets’ idle states. For example, Hudson [13] built visual indicators to show whether someone was talking to someone else, while not revealing the others identity. Other examples of similar awareness displays include: [2, 14]. These displays seemed to synchronize communication in only a limited fashion-- encouraging communication, not regulating it.

Previous work shows that there are appropriate times in a task where disruption from interruption can be minimized. For example, in Cutrell et al.’s [5] study, experimenters interrupted participants by sending instant messages 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. In McFarlane’s experiment described above [19], participants were best able to handle incoming interruptions when they were given control over the timing suggesting that individuals can judge good and bad times to allow interruptions.

The implication of this research is that given the correct information, a co-worker can properly time interruptions; obtaining the information they need while minimizing the disruption they cause [29]. With appropriate motivation, they may use this information to improve synchronization of their interruption attempts with ongoing tasks. Here we extend that work by examining motivation to attend to such awareness displays.

3. RESEARCH QUESTIONS

Consider an abstract help-seeking situation where two parties are collaborating. An Asker, who needs information, wants to interrupt a potential Helper, who is working on another task. An awareness display showing the Helper’s workload could improve outcomes for the pair as a whole by allowing the Asker to get help at a time that is minimally disruptive to the Helper. We believe designers must solve two problems in creating such a display. First, the display must show appropriate information about the Helper’s workload without overwhelming the Asker or violating the Helper’s privacy. Second, designers must solve an incentive incompatibility problem, so that Askers, who are more likely to be motivated by their need for information than the Helper's need for solitude, will postpone their interruptions until the awareness display indicates an opportune time. The sections below discuss the potential benefits of an awareness display, problems in designing the display, and incentives.

3.1 Synchronization

In the best case, the Asker should query the Helper at a time when the Helper is available (i.e., not deeply engaged in a higher priority task). To synchronize the request with availability, the Asker needs feedback about the Helper's task and attentional state. In co-located settings, this information is immediately visible by glancing into someone's office [17] although still sometimes ignored. However, when collaborators are distributed, this kind of feedback is not typically available. We hypothesize that an awareness display providing information about a remote partner's workload could help collaborators time interrupts. Better timing of interruptions would reduce the disruption a help-giver experienced, but would also increase the quality of the help provided. Under a low workload condition individuals are better able to balance multiple tasks with higher performance on both tasks [33] whereas under conditions of high workload the quality of responses to help requests may be degraded because of overload. These considerations suggest the following hypotheses:

Hypothesis 1: *A display with information about a collaborator's workload will increase joint performance.*

Hypothesis 1a: *A display with information about a collaborator's workload will minimize disruption of a help-giver's task.*

Hypothesis 1b: *A display with information about a collaborator's workload will improve help-seeker's performance.*

3.2 Motivation

Askers and Helpers have incompatible incentives. To the Asker, the Helper's time is not worth as much as the information the Helper can provide. When the Asker has no stake in the Helper's performance, the Asker has no motivation to delay communication attempts so that they are convenient for the Helper. Thus, information displays should be used to minimize disruption only when the Asker has appropriate motivation.

To test this proposition, we manipulated the Asker's motivation to minimize disruptions by manipulating the Asker's identification with the Helper. Previous research suggests that being in a group with another and having outcome interdependence is instrumental in developing a common social identity with that person [8, 11]. For example, members of self-managed teams are mindful of the activities of their peers and strive for the welfare of the group as a whole, because team membership is emphasized and teams are rewarded based on the overall team performance, rather than their individual performance, [E.g., 31]. These considerations suggest the following hypothesis:

Hypothesis 2: *Being part of a team with joint rewards will increase the effectiveness of awareness displays for regulating disruption of the Helper.*

3.3 Amount of Information

The amount of information that an awareness display delivers should influence joint outcomes. 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 higher 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., 6, 28]. Because this level of detail can reveal the target's private information and be distracting to the viewer, designers have attempted to provide displays with more abstracted view of co-workers current activities [4, 13].

Dabbish & Kraut [3] provide evidence that abstracted designs can synchronize communication while reducing distraction from the display itself. In their experiment, players in the role of an Asker either saw a display showing a live view of what a Helper was doing, an abstract display summarizing the Helper's workload, or no display. Seeing either the live or abstract display allowed them to time their communication to minimize interrupting the Helper, but their own performance decreased when they viewed live display. Their performance probably dropped because of the attentional demands of viewing the display with high information content.

These considerations suggest the following hypotheses:

Hypothesis 3: *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 3a: *Providing too little information about the Helper's state will lead to ill-timed interruptions and reduce the Helper's performance.*

Hypothesis 3b: *Providing too much information about the Helper's state will require distract the Asker from his or her task*

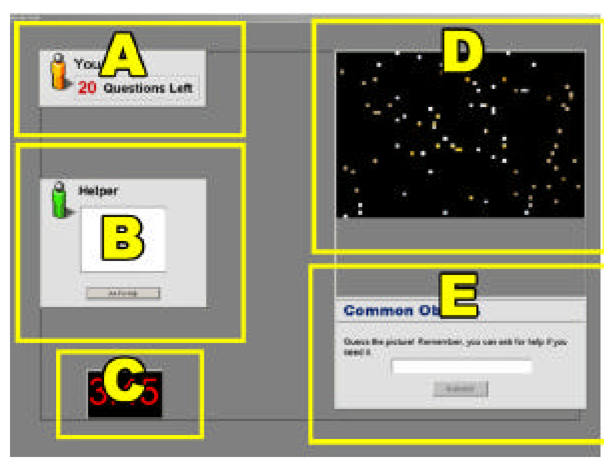

Figure 1. Asker's Screen in Experiment.

Note. Yellow highlights indicate the regions for eye-track and were not visible to participants.

and harm the Asker's performance

4. METHOD

We tested these hypotheses in an experiment in which an Asker is motivated to get information from a Helper. Doing so interrupts the Helper's ongoing work. The task, described below, was adapted from that used by Dabbish & Kraut [3] and is designed to be a stylized version of the situation described by Perlow [23]. The experiment uses a 3 x 2 (display x team membership) factorial design. The Asker has an awareness display that includes either: details of the Helper's work, an abstracted summary of the Helper's workload, or no information about the Helper's workload (see Figure 3). The Asker and Helper are either on the same team, with joint rewards, or have independent rewards.

4.1 Task

The task for the experiment was a 2-player game, where one player (the Asker) depended upon the other player (the Helper) for information. The Asker's primary task was to guess the identity of a partially obscured image as it was slowly revealed (see Area D of Figure 1). Small black squares covering the image were gradually removed over four minutes, while "clues", or random larger squares of the picture, were revealed and then hidden again. The Askers' performance would improve if they watched the squares. Askers score was based on guessing the picture quickly and correctly. The Helper's primary task was the Jumpers video game used by McFarlane [19]. (See left side of Figure 2.) In this game, Helpers tried to save people jumping from a building at random times, by moving corpsmen with a stretcher underneath them. At any moment, the Helpers were trying to save between zero and nine jumpers. Helpers' score in the game was based on saving jumpers successfully.

The Helper could also see the image that the Asker was trying to guess, and thus became an expert concerning the information that Asker needed. (See right side of Figure 2.) The Asker and the Helper were seated in separate rooms. The Asker could send the Helper 20 yes-or-no questions, over the computer, about the picture they were attempting to guess. The questions took over the Helper's screen for at least 5 seconds, preventing Helpers from saving jumpers while the questions were on screen.

This design required both the Helper and the Asker to continually attend to their primary tasks for optimal performance. Interrupting the Helper would interfere with the Helper's ability to save jumpers. An awareness display that distracted the Asker would prevent them from seeing important clues and thus interfere with the Asker's guessing performance.

We manipulated both the amount of information the Asker had about the Helper's workload (the number of jumpers to be saved) and the Asker's social identity (whether they were part of a team with the other player and rewarded as such). We analyzed the rate and timing of the Asker's questions, and their effect on both players' performance.

4.2 Awareness Display

Figure 2. The Jumpers game, played by the Helper

To test our hypotheses regarding the role of awareness information in timing interruptions, we manipulated within subjects the amount of information that the Asker received about the number of jumpers Helpers had on screen.

In each round of the game Askers saw one of the three awareness displays shown in Figure 3. (See Area B of Figure 1). Display order was counter-balanced using a Latin square design. In the *full display condition,* Askers saw a 2.5" x 2.5", real-time replicate of the Helper's screen on their computer, implemented as a Virtual Network Computing window [24]. In the *abstract display condition,* they saw icons representing the number of Jumpers on the Helper's screen. Finally, in the *none condition* they received no information about the Helper's current task.

4.3 Team orientation and reward

To test the third hypothesis we varied the social identity between Asker and Helper. Our prediction was that an awareness display will be more effective when users are motivated to consider a partner's welfare. In the *team condition* Askers were told they were on a team with the Helper, that their rewards would be based on the average of their score and that of the Helper, and that they were competing as a team against other teams for a fifty-dollar prize; they and the Helpers wore matching jerseys. In addition to this, the Askers were shown a picture of their partner, and participated in a social chat with a confederate whom they believed to be their partner. Confederates responded according to a randomly selected chat script recorded from actual participants answering a series of questions. In contrast, in the *independent condition* the Asker was told that their reward was based exclusively on their own performance, and that they were competing with all other Askers for a fifty dollar prize; they wore a jersey of a different color from the Helper's. To account for any experimenter effects, Askers in the Independent condition were shown a picture of a lab assistant and answered the same questions from the social chat via a static web form.

The team manipulation was directed only toward the Askers, because they were the ones with the ability to interrupt their partner and could see the workload displays. In both the independent and team conditions, Helpers were informed that they were on a team with their partner. This was done to control for any affect of team membership on the Helpers' performance in answering questions from the Asker. The Helper's goal was to equally weight the importance of the Jumpers game task and the importance of the incoming questions from their partner.

4.3.1 Time Pressure

In the study by Dabbish & Kraut [3] participants in the role of Asker were rewarded based solely on their accuracy and not the time taken to complete the task.

We suspected that time pressures would strongly affect participants' usage of the displays and the timing of their interruptions. Thus, for this experiment we introduced time pressures by rewarding participants based on how quickly they solved each picture, in order to increase the incentive to interrupt their partner non-sensitively. Without time pressure participants would not have to worry about how long they take to solve each picture, and thus could afford to wait for opportune times to send interruptions whether or not they were part of a team. Thus we believed that a time incentive would increase the salience of team membership and reward structure. Participants who were not part of a team would not feel it was worth waiting for the right time to send interruptions, because time spent waiting actually cost them money, whereas participants who were part of a team would be more likely to wait. Introducing the time incentive should further increase the cognitive load of the Asker. Under this condition the team manipulation should take effect as posited in Hypothesis 2.

4.4 Measuring consumption of attention

To test hypothesis 3b, the current experiment used gaze tracking to accurately determine the attention that different awareness displays consumed. We calibrated a visor mounted ISCAN ETL-500 gaze tracking system to record the number and duration of Askers' gaze fixations in various regions of their computer screen (See Figure 1). In particular, we were interested in the amount of time they spent looking at their puzzle (region D) and the awareness display (region B) versus all other regions (A,C,E).

5. RESULTS

A pair's performance during an individual picture puzzle was the unit of analysis, except where noted. We recorded their actions on 396 puzzles (33 pairs X 3 display conditions X 4 picture puzzles per display). Because puzzles were nested within display condition and pairs, they were not independent. Therefore they were analyzed using a repeated measure mixed-model analysis of

gure 3. Awareness Display Conditions

variance. To examine the consequence of awareness displays, we calculated one-degree of freedom planned contrasts to compare the condition with no display [None] to the conditions where a display was visible [Abstract and Full]. To determine whether the amount of information in the display matters, we also computed one-degree of freedom planned contrasts to compare the abstract display condition to the full display condition.

Our results, reported in detail below, show that Askers in the Team condition used the workload displays to time their interruptions when their partners were least busy, while Askers in the Independent condition did not. This difference in interruption behavior resulted in a significant performance benefit for the Helper during the Team condition. In addition, the eye-tracking data showed that the full information display consumed substantially more attention than the abstract information display in both the Team and Independent conditions. Thus there is a trade-off between attention required by an information display and its potential benefits if users are motivated to interrupt sensitively.

5.1 Performance Results

5.1.1 Manipulation check

Askers completed a 10-item survey measure of group identity to check the effectiveness of the social identity manipulation [11]. The inter-item reliability for the measure was satisfactory (Cronbach's alpha=.82). Results indicate the manipulation was successful. As planned, Askers in the Team condition identified more strongly with their partner than did Askers in the Independent condition (Means: Team=4.24, Independent=3.75, SE=0.16), with $t(30)= 2.23$, $p<0.05$.

5.1.2 Helper's performance

The Helper's performance was measured by the percent of jumpers saved during each picture. Consistent with Hypothesis 3a, the Helper's performance improved significantly when the Asker received information about the Helper's workload. The Helper was able to save approximately 10% more jumpers in the abstract display condition than in the no display condition, and 8% more jumpers in the full display condition than in the abstract display condition. This result is consistent with Hypothesis 1a that a Helper's performance would increase if the Asker were given information about their current workload. Means for the display conditions were: None= 51.7%, Abstract = 56.1%, Full = 58.8% with a pooled standard error of 2.0%. The planned contrast comparing the None display to the Abstract and Full display conditions was $F(1,352)=11.03$, $p<.001$).

There was also a significant difference in performance for the Helpers during the team condition versus Independent condition. In the Team condition Helpers saved 11% more jumpers than in the Independent condition ($F(1,31)=3.31$, $p=0.07$), Means were: Independent=52.6%, Team =58.6%, with a pooled standard error of 2.0%.

These main effects of the display and team manipulations must be qualified by the significant display by team interaction shown in Figure 4. The display condition influenced Helper performance only when the Asker thought they shared a team identity (F(1, 352)=11.32, *p*<0.001). Thus, Hypothesis 2, that workload displays improve performance more when an interrupter is motivated to be concerned with a partner's performance, was supported.

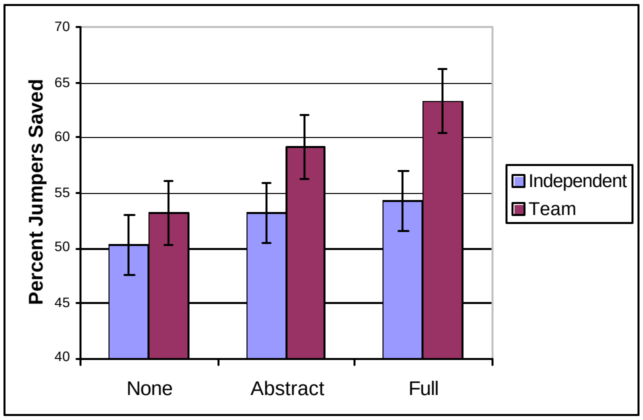

Figure 4. Helper Performance by Display Condition for Team versus Independent conditions.

5.1.3 Asker

The Asker's performance was measured by the accuracy in their identification of the picture puzzles and the time, in seconds, it took them to identify each picture. There was no effect of awareness display condition on the Asker's accuracy at identifying pictures (F(1,352)=1.00, *p*=0.32; mean accuracy = 52%). Nor was there an main effect of the awareness display condition on the time it took Askers to identify the pictures (F(1,352)=0.70, p=0.40; mean time to respond = 152 seconds). There were also no effects of team condition on Askers' accuracy or time to complete puzzles (F(1,31)=0.18, p=0.67) and no significant interactions (F(1,352)=0.005, p=0.93). Thus, it may have been the case that waiting to send an interruption in this situation did not influence the Asker's performance, and although Independent Asker's did not wait they could have afforded to.

5.2 Interruption Behavior

We examined Askers' interruption rates and when they asked Helpers questions to determine whether they were timing their interruptions and whether this timing could account for the display by team interaction in Helper's performance. Because these measures directly relate to the research questions, but were not part of the participant's incentive structure, they should reveal the impact of the manipulations of interest [18]. We also had Askers describe to us their strategies for timing interruptions.

5.2.1 Interruption Rate

The number of questions sent during each picture was used to calculate the Asker's interruption rate, or average number of questions sent per minute. Askers using information in the awareness displays to time their questions would have to synchronize their question with particular levels of the Helper's workload. This meant that when timing was being used, the interruption rate should be lower than when interruptions were not being timed.

Askers did not have a higher rate of interruptions when they had no workload display. (The contrast comparing the None condition versus Abstract + Full was F(1,352)=2.42, p=0.12). Mean questions per minute were: None=1.80, Abstract=1.74, Full=1.53 with a pooled standard error of 0.12.

There was a significant main effect of team condition on interruption rate. Askers in the Independent condition sent 22% more questions per minute than did Askers in the Team condition (F(1,31)=4.66, *p*=0.03). Means for both conditions were: Independent=1.92, Team=1.50 with a pooled standard error of 0.15. There were no significant interactions of team with display condition for interruption rate (F(1,352)=1.86, *p*=0.17).

There are two possible explanations for the difference in interruption rate across team conditions. One is that Askers in the Team condition simply sent fewer interruptions overall out of concern for their partner's performance, without respect to the exact interruption timing. Alternatively Askers in the Team condition may have been timing their questions sensitively and thus sent questions less frequently. To determine the appropriate explanation we looked at whether interruption timing differed between Team and Independent Askers across display conditions.

5.2.2 Interruption Timing

Askers sent approximately 4 questions to the Helper during each puzzle and thus interrupted them 4 times. To see whether Askers were timing these interruptions, we examined how busy the helper was when each interruption arrived. If Askers in the Team condition were timing their interruptions sensitively, then the Helper's workload should be lower for those interruptions than for Independent interruptions. We calculated a workload measure – the number of jumpers on the Helper's screen—for each of 1480 questions.

Compared to Askers with no workload displays, Askers with workload displays sent their questions when Helpers were less busy. (Mean number of jumpers on screen when an interruption was sent: None=1.97, Abstract=1.76, Full=1.85 with a pooled standard error of 0.06. For the planned comparison (F(1, 1442)=4.50, *p*=0.03)).

Compared to Askers in the individual condition, Askers in the team condition sent questions when Helpers were less busy. (The means for each of the team conditions were: Independent=1.97, Team=1.75 with a pooled standard error of 0.05. F(1,1442)=17.84, *p*=0.002) The difference here suggested that team members were indeed timing their questions.

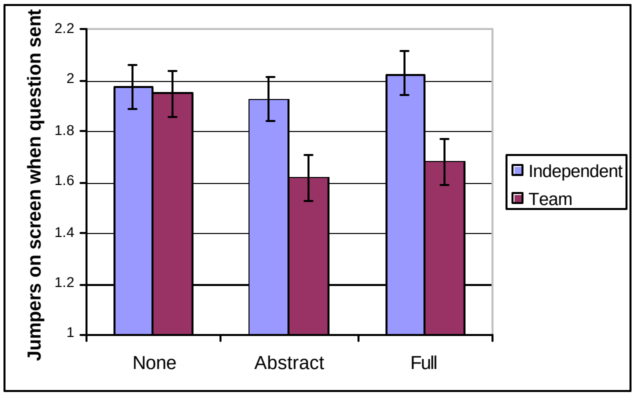

Figure 5. Interruption timing by Display Condition for Team versus Independent conditions.

These main effects for presence of the workload display and the team condition must be qualified by the significant display by team interaction, shown in Figure 5. There were no differences in interruption timing across display conditions for Askers in the Independent condition (F(1,1442)=0.43, *p*=0.51). On the other hand, Askers in the Team conditions asked questions when fewer jumpers were on screen when they had either the Abstract or Full workload display available compared to the None condition (F(1,1442)=7.79, *p*=0.005).

These interruption timing differences coupled with the significant performance increases for Helpers during the team condition indicate that Askers in the team condition were indeed using the information displays in timing their interruptions to arrive at opportune moments - when fewer jumpers were on the Helper's screen - while Independent Askers were not. Thus we find support for Hypothesis 2, that appropriate motivation for timing interruptions sensitively will increase the effectiveness of the awareness display.

5.2.3 Self-report interruption strategies

To evaluate how participants were using the information displays to time interruptions we also collected qualitative self-reports about Askers' strategies for when to ask questions. Following each round Askers described their strategy for deciding when to send interruptions to the Helper.

Perhaps the most striking aspect of this self-report data is that a majority of Askers in both the team and independent conditions reported using the workload displays to time their questions. Over 60% of Askers in the experiment (evenly distributed across team conditions) reported using the information displays in timing their questions when the displays were available, during the Abstract and Full information conditions. However, there were differences in the nature of interruption strategies between the abstract and full conditions.

In the abstract condition 58% of Askers reported using the display to time their questions (Team=62%, Independent=58%). Their strategies were relatively simple, based on defining a threshold number of jumpers. For example:

> *"I asked her when she had less than 2 people around on screen. Otherwise I left her alone."*

For the full display condition 67% of Askers reported using the display to time their questions (Team=69%, Independent=64%). In this condition interruption strategies were more complex, often using detailed information in the Helper's game as a cue. Some examples include these self-reported interruption timings:

> *"when there were few players on the screen, or it seemed like they were about to go into safety"*

> *"I tried to ask Player 2 right as a jumper hit one of the mats, so he would have plenty of time to answer and return to the game"*

In many cases it was difficult for the Asker to articulate exactly how they timed their questions, and they often reported watching for times when the Helper "*wasn't too busy*" or their interruption "*wouldn't hurt his game*". The following are typical strategies of this type:

> *"I tried to asked questions when I felt that I wasn't interrupting player 2."*

> *"I also tried to time the questions at times when he was not at risk of losing jumpers"*

These more general responses imply that the Askers watched the Helper's game carefully to determine "opportune" times to interrupt, and these situations were perhaps too complex to describe in a brief self-report.

Because the Helper's performance was best during the Team condition we expected self-reports for Team Askers to be qualitatively different than for Independent Askers. However, this was not the case. There were no qualitative differences in the types of strategies reported by Team Askers versus Independent Askers.

The self-report data suggest that both Independent and Team Askers were timing their interruptions to be sensitive. However, the performance data for the Helper, and the interruption timing data attest to the fact that Askers in the team condition were substantially more sensitive in their timing.

5.3 Eye tracking Data

The results thus far suggest that a workload display can help people time their interruptions to be minimally disruptive when there is incentive for them to use this information. Intuitively it seems that more information in the display should be better. The more complex timing strategies that Askers used when they had the Full display may be better than the simple decision rules they used with the Abstract displays. However, the results from Dabbish and Kraut [3] demonstrate this may not be the case. Askers in their study experienced performance deficits in a full information condition.

Because the current experiment rewarded Askers for being fast, we did not see performance differences when askers where using different displays. To look at their attentional load across the display conditions in more detail, we used gaze tracking equipment that automatically recorded where they were looking. Attention consumption is an indication of how visually and cognitively taxing the displays were. Thus, gaze tracking allowed us to test Hypothesis 3b, that Askers may be harmed by the attentional load of a high information display. By comparing the attentional demands of the two displays we can indirectly examine their effects on the Asker.

The gaze tracking system was calibrated to record the number and duration of Askers' gaze fixations in various regions of their computer screen (See Figure 1) with a fixation threshold of 50msec [15]. In particular, we were interested in the amount of time they spent looking at their puzzle (region D), the awareness display (region B) and the other regions (A, C, E). We also looked at the percent of fixations in each region of the screen, the average fixation duration for that region, and fixation scan paths.

Eye-gaze data was collected for an entire round (4 puzzles) so the unit of analysis for the eye-tracking data is one round in the game. Due to calibration issues with the gaze-tracker some participants' data could not be used so only 21 out of the 30 pairs are considered. Thus the number of rounds analyzed was 63 (21 pairs x 3 display conditions = 63). Because rounds were nested within pair, they were not independent. Therefore they were analyzed using a repeated measure mixed-model analysis of variance. To test Hypothesis 3b we were interested only in the difference between the attention consumed by the abstract display and the full information display. Because of this we report only the one-degree of freedom F-test comparing results for the Abstract display condition to results from the Full display condition. We include mean values from the None condition to provide a baseline.

5.3.1 Gaze Percent

Here we define gaze percent as the proportion of total time spent fixating in an area of interest during an entire experimental round, or the sum of all individual gaze durations in that area [15]. As expected, Askers spent significantly less time attending to their primary task—guessing the identity of their picture—and more time monitoring the awareness display as information content in the display increased. As Table 1 shows, participants dropped their attention to their primary task by 6% when they had the full display rather than the abstract one (from 66% to 62% of total task time). Instead, they increased the time attending to the awareness display by 19% as they moved from the abstract display to the full one (from 16% to 19%).

There was no main effect of team condition on gaze percent ($F(1,19)=0.31$, $p=0.58$), and no significant interactions between display condition and team for gaze percent ($F(1,37)=1.03$, $p=0.37$).

Table 1. Eye-tracking data and statistics for each display condition

Dependent Variable	***Screen Area***	***Display Condition***			***Statistics***	
		None	Abstract	Full	F	*p*
Time viewed (percent)	Awareness Display	16.7	15.6 [a]	19.2 [b]	8.66	0.006
	Primary Task	64.9	66.1 [a]	62.4 [a]	3.29	0.08
Proportion Fixations (percent)	Awareness Display	17.6	15.6 [a]	20.0 [b]	11.8	0.002
	Primary Task	63.6	65.9 [a]	61.6 [b]	8.50	0.007
Mean Fixation Duration (msec)	Awareness Display	622	623 [a]	763 [b]	4.76	0.03
	Primary Task	682	600 [a]	813 [b]	8.32	0.007

Note: Values with differing super scripts are significantly different.

5.3.2 Proportion Fixations

This metric indicates the proportion of total fixations that were on an area of interest. Consistent with Hypothesis 2b, Askers fixated about 33% more on the full information display than the abstract display condition. The statistics and mean for each condition in percent of total fixations are listed in Table 1.

The number of fixations on a particular display element of interest relative to total number of fixations should reflect the importance of that element. More important display elements will be fixated more frequently [7, 9, 15]. Thus the increased proportion of fixations on the full display indicates its prominence on screen and importance during that condition as compared with the abstract display.

In addition, during the full information condition Askers fixated significantly less on their primary task area (Area D in Figure 2) In a planned comparison of Full versus Abstract $F(1,37)=8.50$, $p=0.007$. This result suggests that during the full condition the awareness display was distracting participants from their primary task. There was no main effect for team on gaze percent ($F(1,19)=0.13$, $p=0.72$), and no significant interactions between display condition and team for gaze percent ($F(1,37)=0.96$, $p=0.39$) indicating that this distracting effect occurred for both Team and Independent Askers.

5.3.3 Mean Fixation Duration

Mean fixation duration is the average length of a fixation on an area of interest. Longer fixations are an indication of a participant's difficulty extracting or interpreting information from a display [7, 9, 15]. Our results show that the average fixation duration for the full condition was 22% longer than for the other two conditions (see Table 1).

In this case longer fixations during the full condition may indicate that participants had more difficulty parsing the information in the full display versus the abstract display. Our qualitative data and the results from Dabbish & Kraut [3] indicate that they may have spent more time and effort processing the information in the full display than the abstract display.

During the full condition we also see a 36% increase in fixation duration for the primary task area (Area D in Figure 1) from the Abstract condition in a planned comparison (Table 1). The presence of the full display may have made processing of the primary task more difficult as well, resulting in longer fixations when attempting to process the primary task. Dealing with the informationally rich full display may have increased participants' cognitive load and thus made the primary task more challenging.

There was no main effect of team condition on fixation duration for the display or primary task area (F(1, 19)=0.73, p=0.39), and no interaction of team by display (F(1, 37)=0.45, p=0.64).

Table 2. Summary of hypotheses and related results

Hypothesis	Supported	Discussion of Results
1a. A display with information about a collaborator's workload will minimize disruption of a help-giver's performance.	Yes	Interrupters used awareness display to time their questions when they had motivation to do so.
1b. A display with information about a collaborator's workload will improve help-seeker's performance.	No	Unable to test with performance data due to lack of variance.
2. Team identity and joint reward structure will increase utility of display	Yes	Askers in a team used information displays to time interruptions sensitively resulting in significant performance gains for the Helper.
3a. Too little information in the display will harm the Helper	Yes	Helper's performance was significantly worse during conditions where the Asker had no information.
3b. Too much information in display will harm the Asker	Yes	Full information display consumed significantly more attention than an abstract display.

6. DISCUSSION

This experiment investigated the value of a workload display for coordinating interruptive communication. We found that under conditions of shared rewards and common identity (Hyp 2), awareness displays can indeed be beneficial for reducing the disruption associated with interruption (Hyp 1a). In our experiment the Helper's performance was significantly better during conditions when the Asker had information about their workload (Abstract + Full conditions) and had motivation to use that information (Team condition). The Asker's performance was unaffected by the information displays (Hyp 1b). Our results did not indicate that a display with high information content provides any additional performance gains for the Helper over an abstracted display (Hyp 3a). In this setting a high information display required substantially more visual attention and was more cognitively demanding than an abstract display (Hyp 3b). Table 2 provides a summary of our hypotheses and the support from our experiment.

6.1 Motivation to Interrupt Sensitively

Our results showed that the Asker timed their interruptions sensitively only when they were motivated to do so. This sensitive timing resulted in higher performance for the Helper. In this experiment, we manipulated motivation to interrupt sensitively by creating a team identity with the interruptee.

A team identity is but one way to motivate people to interrupt at appropriate times. Friendship, reciprocity, joint history, or anticipation of future interaction may all build relationships among people motivating them to time their interrupts.

With interactions among strangers (e.g., the proverbial insurance salesman calling at dinner), one might induce a similar motivation by using pricing schemes. For example, it could become more costly to interrupt someone the busier they are. Pricing should regulate the timing of interruptions without revealing information that would compromise the target's privacy.

At the same time, motivation without information is insufficient for successful coordination across a distance. In this case interrupters may simply decrease their amount of communication overall, harming themselves, because they cannot coordinate their interruptions with the target's availability. In our experiment Askers in the Team condition reported doing this when they had no workload display. For example, two Askers reported the following strategies for timing their interruptions during the no workload display condition:

"I tried to ask fewer questions of my partner so as not to distract."

" I didn't ask, because I didn't know what was going on on their end..."

6.2 Attentional Demands

In our experiment, the majority of Askers reported using the workload displays to time their interruptions, but only the Team Askers did so to a substantial degree. In addition, both the Team and the Independent Asker's were affected by the attentional demands of the workload displays, whether or not they used the display to time interruptions. Askers in both incentive conditions spent significantly less time looking at their primary task when they had the informational display and looked more frequently at the full information display than the abstract information display. Eye-tracking data suggests that this may have been due to difficulty in processing the information in the full display.

In this experiment, the display conditions did not affect the Askers' task performance, even though Askers had a performance drop when using a full information display in a similar experiment [3]. We believe rewarding Askers with a time-based incentive made their puzzle completion time an insensitive measure of the influence of the displays on task performance [18]. These time pressures made the experimental situation more realistic, but at the same time reduced the variance on our outcome measure of time.

To overcome this problem, we looked at other data, particularly the eye-tracking data, to understand the impact of the different awareness displays on the Asker's behavior and test Hypothesis 3b. The awareness displays distracted participants from their primary task and did so more, the more information content the awareness display contained. Although the additional information seemed to cause Askers to use more complex interruption strategies, it provided no additional benefit to the Helpers.

These results suggest that an abstract display provides the best tradeoff between useful information and distraction, particularly in cases, such as the Independent condition, when motivation to use the display is not guaranteed. In the case where the interrupter is not motivated to use the display, an abstract display provides the target with a certain level of privacy and shields the interrupter from the attentional load of a high information display that provides no utility. In settings where the interrupter is motivated to use the workload display to time their interruptions, an abstract display provides them with the minimal amount of information they need without compromising their primary task performance.

Ultimately, however, the task setting must be taken into consideration. Our study used a continuous attention task with high temporal demands. High information workload displays may be harmful in such a setting, but could be useful in other task settings. For air traffic control tasks a full information workload display would not be suitable because of the visual attention and temporal demands of the primary task. However, for a typical knowledge work task such as editing a document, an interrupter could attend to a full information display and not miss information in their primary task because the task environment is fairly stable. In addition, in these places full information workload displays may provide other benefits such as increased feelings of involvement with a remote co-worker.

7. DESIGN IMPLICATIONS

Although this experiment was performed in the laboratory using a highly stylized task, we believe these results can be applied to the design of awareness displays in domains requiring tight coupling between co-workers in a dynamic environment. These results may directly apply to the bond-traders described by Heath et al [10], who maintain awareness of their colleagues activities on a minute-by-minute basis to coordinate communication with them and inform their own activities. Air traffic controllers, remote surgery teams, and military command and control crews may operate under similar constraints.

The logic of our analysis applies more broadly, even if the details of the particular tasks and displays we used do not. To balance the tradeoff between the amount of information presented and the incentive to use that information, electronic communications systems could regulate the awareness information they provide based on an interrupter's inferred motivation to use that information. For example, in designing a corporate instant messaging client, one could apply these results by presenting a workload awareness display of a target's activities only to people internal to the user's project or company, and no such display to people outside the company.

Currently, the "away" and "busy" messages which various instant messaging clients use are too temporally coarse to provide sufficient information for synchronizing interruptions. However, our results and those from Dabbish & Kraut [3] suggest that richer awareness displays such, as those used in the Cruiser [6] or Montage system [28], may be too distracting to users, to say nothing of the privacy issues they raise. An abstracted display may provide the optimal solution.

An important technology design question then is how to distill rich, multidimensional information about an individual's current activity into a format that is easy to visually and mentally process. In our experiment this was trivial because our task was designed so that workload equated to a directly measurable aspect of the Helper's task, the number of jumpers on their screen. Work on automated sensing of availability using machine learning techniques can do a reasonable job of assessing workload for more complex tasks. (Horvitz; Hudson; & Begole) are able to infer an individual's availability in an office setting by looking at input from multiple sensors in the environment. These types of systems could drive an abstracted awareness display in an office setting as in (Fogarty, Hudson, and Lai, 2003). The next step then becomes investigating how our results generalize to these more complex task domains such as the tasks of knowledge workers.

Our results provide hope for the problem of communication coordination during distributed work. Displaying information about a remote collaborator's workload helps both parties if that information is in an easy to process format and the potential interrupter has incentive to be polite. Interrupters can still make use of a synchronous communication medium such as instant messenger and thus not have to wait for help. Targets get to deal with communication at more convenient times that don't compromise the rest of their work, resulting in the best outcomes for the group as a whole.

8. ACKNOWLEDGMENTS

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