A Study of Co-worker Awareness in Remote Collaboration over a Shared Application

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Abstract

Following recent developments in groupware that allow teams of co-located and distributed users to work simultaneously on a shared application, differences in the relative awareness of co-located and remote users have been identified. This paper examines users' perceived awareness of others and their observed direction of attention in this context. A study of six groups of three users distributed across two sites reveals that the disparity in awareness between co-located and remote users may not be such a problem as previously suggested. Results also show that for the tasks employed herein, users rely predominantly on cues within the shared application such as multiple cursors, rather than the videoconference channel, to remain aware of the actions of their collaborators. The study also provides further evidence for the importance of additional awareness cues, such as 'video arms'.

Keywords

Collaborative computing, mixed presence groupware, telepresence, awareness, attention, presence disparity.

ACM Classification Keywords

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – Computer-supported cooperative work, Synchronous interaction, Collaborative computing.

The ViCAT table, with a shared multi-cursor video editing application displayed on the horizontal screen ('task space' [1]) and remote collaborators showing on the vertical screen ('person space' [1]).

Introduction

Previous investigations into remote collaborative computing and support for teams of users distributed across multiple sites have led to the notion of mixed presence groupware [10]. Mixed presence groupware (MPG) allows both co-located and distributed users to share a visual workspace in a synchronous manner. Presence disparity [10] in MPG arises from the presence of remote collaborators being weakly perceived relative to the presence of co-located collaborators. Despite some observations of presence disparity [10], to date there has been very little detailed investigation of this problem.

Presence, or awareness, is a complex concept to define and evaluate. Previous measurements have included attention allocation, situational awareness and presence questionnaires for telepresence [9], employing specific tasks requiring awareness, observing collisions and following the direction of eye gaze for co-located collaboration [7], and recording the direction of spoken utterances in MPG [10].

Tools and approaches for improving awareness in remote collaboration abound. Aside from conventional video conferencing, techniques like video arms [11] have been proposed for use in a shared application [10,13]. Facetop [4] goes some way towards enabling the set of subtle interactions that fall between communicating with remote collaborators and editing a shared artifact. Many researchers have used multiple cursors, and recently a toolkit known as the Transparent Interface Device Layer (TIDL), which supports mixed presence groupware, has emerged [6]. Cursors can act as telepointers [3] in addition to providing full control over a shared application.

Remote Collaborative Computing using ViCAT

The ViCAT table's design allows remote groups to interact simultaneously to perform a common goal. The table comprises a large vertical rear-projected screen, on which remote collaborators are shown, and a large horizontal screen, onto which the shared application is rear-projected (see inset). AccessGrid [2] is used to provide teleconferencing video over IP of remote coworkers. TIDL [6] provides simultaneous input from multiple mice (and keyboards) both co-located and distributed, and supports legacy Java applications with no integration effort. ViCAT differs from the Facetop overlay by supporting more than 1-2 users at each of a number of sites (more than two) [6], although its cursor-based telepointers lack the directness of FaceTop's natural gesture. Software prototypes developed for ViCAT include military planning [6], data visualization [6], multimodal video editing and games.

Subjects and Tasks

Following two pilot groups, six groups of three volunteers participated in the study. Of the 18 participants, 11 were male, 7 were female, 8 were aged between 20 and 30, 8 were aged 30-40, and 2 participants were aged 40-50. Two members of each group were located standing at the front of the table, with the avatar of the remote participant displayed on the vertical screen and the shared application on the horizontal screen. The remaining group member was seated in another room in front of two vertical monitors, one (17 inch) displaying the shared application and the other (45 inch) showing the video of the participants at the table. At the table, a teleconferencing microphone and speakers were employed, while the remote participant used a

Screen shot of the SearchGame (configuration iv: each player on a separate team), with the three triangular mouse cursors of the individual players shown in different colours.

microphone headset. Video recordings were made at both locations.

The study tasks were based on two Java applications, onto which TIDL [6] was overlaid. All participants simultaneously had full control over the application at all times, so that the only difference from a single-user application was the presence of three cursors. Moreover, each participant saw exactly the same application state on their display at all times.

The first task was to play a multicursor version of the popular minesweeper game, based on the single-user JMines [8]. Subjects were instructed to work together to uncover all the mines. Since some groups stumbled on a mine very quickly, this task was repeated to produce a minimum playing time of at least 2 minutes. The second task was to play a search game whereby a predefined sequence of abstract shapes (see lower half of inset) needed to be found in the correct order from a large array of shapes (see upper half of inset). Each subject/team had to find the same sequence of shapes, and shapes from their sequence disappeared as they found each correct shape, similarly to the search game in [5]. This game was played four times, once with each of the following configurations, ranging from more collaborative (i) through to more competitive (iv):

i. All three subjects played together (all on same team)
ii. Subjects at the table (co-located team) played against the subject in the nearby room
iii. One subject at the table and the subject in the nearby room (distributed team) played against the other subject
iv. All three subjects played for themselves

Measurements

This study aimed to gain an indication of both subjects' perceived awareness of other participants and their observed direction of speech and eye gaze. At the conclusion of each task, subjects were asked how aware they were of the co-located and remote participants (5-point Likert scale). Video recordings from each task were analyzed to observe the portion of each task that subjects were looking at another subject (rather than at the shared application), and how many times they spoke to another subject.

In order to understand the importance of the multiple mouse cursors, at the conclusion of each task, subjects were asked to rate how aware they were of the other cursors (5-point Likert scale). At the conclusion of the study, participants were asked whether the videoconferencing or the mouse cursors gave better awareness of what other participants were doing, and also how easy it was to follow the three cursors (5-point Likert scale).

Awareness of Co-located and Remote Participants

Averaged across all groups and tasks, participants perceived that they were more aware of the remote player than the co-located player, and the distribution of score differences between awareness of co-located and remote players is shown in figure 1. In terms of primary visual attention, participants looked at co-located and remote players respectively 5% and 95% of the time that they were not looking at the shared application, although co-located participants were very probably aware of each other through peripheral vision. In terms of conversation, participants often spoke to all players, however they spoke to co-located and remote players for 34% and 66% respectively of the remaining utterances. This could be interpreted to mean that users were more aware of remote collaborators (who physically faced them) than co-located collaborators, or that more effort is required to establish and maintain collaboration with a remote participant than a co-located one. Thus, in terms of presence disparity, we observed the reverse to [10] for these tasks, i.e. that if there was any conversational disparity at all, it favoured remote rather than co-located participants.

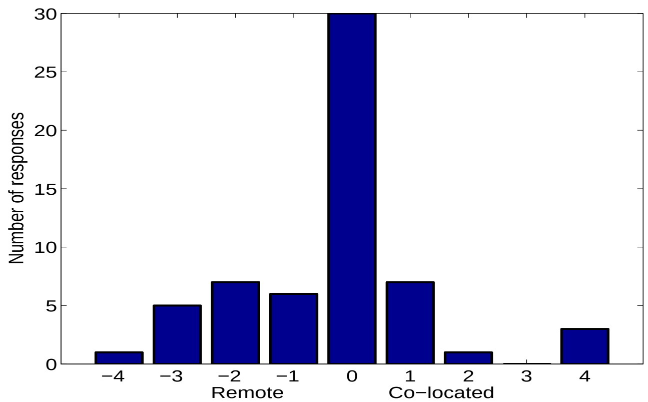

figure 1. Distribution of score differences between perceived awareness of co-located and remote players across all subjects and tasks (0 = equal awareness of co-located and remote, negative values = more aware of remote than co-located).

Awareness of Video and Mouse Cursors

Thirteen of the total 18 subjects perceived that the remote players' mouse cursors gave them better awareness of what remote players were doing than the video telepresence. This concurs with the result that subjects spent on average 96% of the task duration looking at the shared application. Of the five participants who rated the video as giving better awareness of remote players, some informally commented that the audio channel was very important for them. The relatively large use of speech compared with eye gaze by subjects tends to confirm this. No support was found for the suggestion that consequential communication (i.e. visibility of another's body) was inadequate [10] – subjects only glanced at each other on average 4% of the task duration, across a total of 34 minutes for all six groups.

Comparison Between Tasks

Examining subjects' perceptions and measurements of speech and gaze usage by task revealed that all five indicators of awareness decreased on average as the study progressed, as seen in figure 2 (note that the chronological order of the tasks matched the order of the tasks on the horizontal axes of fig. 2). Likely reasons for this include the decreasing need for collaboration required by each successive task, and the increasing familiarity of the participants with each other and with the interface and tasks.

The average indicators in figure 2 all appear grossly correlated, suggesting some consistency between participants' perceived awareness and the physical manifestations of their awareness (speech and gaze usage). During the search game with a co-located team (ii), participants both perceived increased awareness of their co-located partner (relative to other search game tasks), and spoke much more to their co-located partner (96% of all player-specific conversation, compared with 34% over all tasks). During the search game with a distributed team (iii), participants by contrast did not perceive an increased awareness of their remote partner (relative to other search game tasks), but they did speak much more to their remote partner (98% of all player-specific conversation, compared with 66% over all tasks).

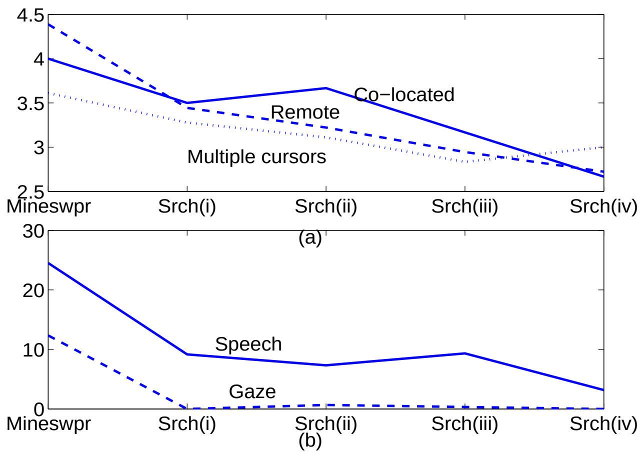

figure 2. (a) Average participant perceptions of their awareness of co-located (—) and remote (- - -) players and multiple cursors (. . .) by task (1 = Unaware, 5 = Very aware). (b) Average number of spoken utterances (—) and duration (sec) of gaze directly at any other participant (- - -) by task.

Informal Observations

Of the six groups, two had a highly extroverted and collaborative approach to the study (these participants had worked or lived together), discussing almost every detail of the tasks. On the other hand, two groups were almost silent during the study and adopted a highly individualistic approach to the tasks. This was a significant source of variability in the results. Direct parallels exist between the use of gesturing in this study and that reported in the study of Ha *et al.* [5], where similar games were studied. In [5], virtual gestures (i.e. mouse cursors) for communication were found to be problematic because these do not have the same level of physical presence as physical gestures and thus do not command the same level of awareness. In this study, subjects at the table tended to initially use physical gestures, then remembered (or were instructed by the remote participant!) to use virtual gestures. Virtual gestures involved shaking the mouse cursor around the point of interest to elicit attention. In one or two cases, however, subjects at the table actually used virtual gestures and simultaneously pointed with their other arm, to obtain the degree of communicative presence that they desired.

Design Implications

The relative awareness of co-located and remote participants found in this study is difficult to generalize, as this may be dependent on the specific hardware and experimental configuration employed. Despite the less convincing evidence for the notion of presence disparity posed by this study than in [10], the significance of digital arm shadows [11] was supported. This is because the 'task space' [1] was the point of attention and concentration for users around 96% of the time, and because users were directly observed to employ the mouse cursors for communication purposes.

In this work, the visual component of the video was useful mainly for the social context that surrounds the task (e.g. preliminary and follow-up discussion and informal chatter). Audio was critical for virtually all groups. This may point to collaborative solutions for shared applications that do not rely heavily on high-bandwidth video (or make only occasional use of it), so long as a high quality audio channel can be maintained. Considering that this study investigated shared application use by only three users, methods for improved cognition of multiple cursors are needed (similar implications were raised for co-located collaboration in [5]), although perhaps less so for more realistic shared applications (e.g. editing a document) that require less intense simultaneous multi-user input. Subjects' hearing and peripheral visual perception appears to be important in collaboration over shared applications, but the limitations of this study preclude any specific insights in this respect.

Conclusion

This paper has investigated users' relative awareness of co-located and remote participants both in terms of user perception and observations of the direction of user attention. For this experimental configuration, the notion of a presence disparity that favours awareness of co-located users appears not to be supported, and if anything this disparity was seen to favour awareness of the remote participant. Awareness cues within the shared application, such as multiple cursors or arm shadowing, appeared to be of most benefit to users, who were observed to spend 96% of their time looking at the application during the tasks. Visual cues from a video channel seemed to be of secondary importance during work on a shared application, providing the audio channel between remote sites is preserved. This study suggests a rich array of future research, including a more detailed investigation of the different types of awareness involved in multi-user application sharing, methods for improved cognition of multiple cursors or remote telepointers, investigation of evaluation methods that can account for subjects' use of hearing and peripheral vision, and similar studies for different types of tasks and larger numbers of users in a range of different physical configurations and orientations.

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