Impact of Seating Positions on Group Video Communication

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ABSTRACT
In this study, we examine how changes in seating position across different sites affect video-mediated communication. We experimentally investigated the effects of altering seating positions on conversations in four-person group communication, two-by-two at identical locations: distant parties seated across from each other vs. distant parties seated side-by-side. In the latter seating arrangement, we found that speaker switches were more evenly distributed between distance-separated participants and co-located participants at points without verbal indication of the next speaker. Participants shared a higher sense of unity and reached a slightly better group solution. These findings demonstrate the importance of providing people with various seating arrangements across distant sites to facilitate different group activities.

Author Keywords
Computer-supported cooperative work, video-mediated communication, group-to-group meeting, seating position, conversational analysis, empirical studies

ACM Classification Keywords
H.4.3 Information systems applications: Communications applications–Computer conferencing, teleconferencing, and videoconferencing. H.5.3 Information interfaces and presentation (e.g., HCI): Group and organization interfaces–Computer-supported cooperative work, Synchronous interaction

INTRODUCTION
Seating position is one simple and convenient way to augment or reduce certain types of social interaction in face-to-face settings. Previous research in the field of proxemics [9] has shown that seating positions significantly influence speech patterns among discussion members [10, 12]. Since different seating positions facilitate different group activities, group members often alter their seating positions based on discussion goals [8].

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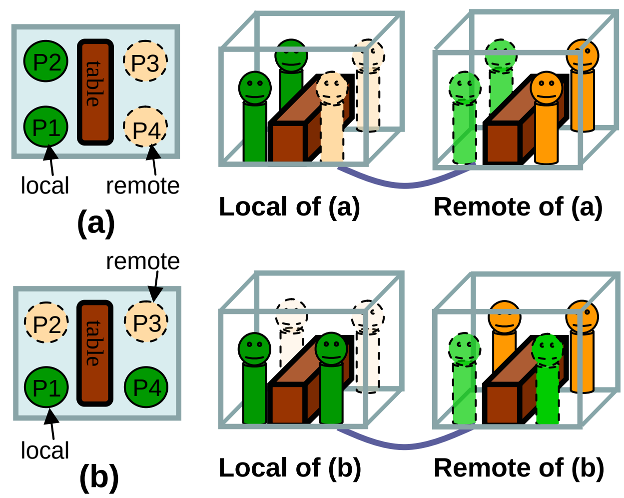

Figure 1 Two types of seating positions for four-person (two-by-two) discussion: two people seated in identical locations: (a) side-by-side and (b) across from each other.

While video-mediated communication has long been touted as the replacement for face-to-face communication, current video conferencing systems, particularly those allowing group-to-group meetings [2, 6, 19], do not allow distant parties to take various seating positions. People in distant locations typically sit across from each other (in front of the screen) facing the distant parties, and people in the same location sit side-by-side. While people in the same location can switch their seating positions, this is impossible between people in distant locations.

In our long experience using such video conferencing systems, we have encountered several situations where distant parties met aggressive discussions. Sometimes members had difficulty organizing discussions between distant parties. Similar phenomena have been found elsewhere [4, 1, 23]. Although such phenomena reflect various factors (e.g., [4,1]), we felt that constraints on seating positions (i.e., distant and local parties always sit facing each other) might be one factor that exacerbates the problems between distant sites.

Based on our experience and previous studies, we started to speculate how altering seating positions across distant sites might affect communication between distant members. For example, would changes in seating position across different sites reduce the unbalanced distribution of speaker switches between distant sites? Would changes in seating position improve the member's sense of unity between distant sites and help them reach better conclusions? Answering these questions is important for the design of distant collaborative environments for various group activities.

In the remainder of this paper, we first draw on prior research and predict how changes in seating positions across distant sites might influence the speech patterns, the sense of unity, and the quality of group solutions in video-mediated communication. Next, we present a system called "t-Room" that enables various seating positions among people in distant locations. Then, using t-Room we describe a laboratory study that compared four-person (two-by-two) discussions in two different seating positions (Figure 1): two people sitting in the same location side-by-side or across from each other. We conclude with a discussion of the implications of our findings and issues raised by our study.

PREVIOUS WORK

Nonverbal Directional Cues

Nonverbal directional cues such as gaze, deictic gestures, head turnings, and body orientations play a significant role in group activities, including the regulation of turn-takings [14], trust development [24], and consensus building [17]. When directional cues are not correctly transferred across distant sites, such collaboration tends to be rather ineffective [11].

Video Conferencing Systems

Given that nonverbal cues are crucial to group conversations, a variety of video systems are being developed to preserve those cues between distant sites, including MAJIC [22], Hydra [27], GAZE-2 [31], and MultiView [19].

Results have so far suggested that such systems can improve several aspects of conversations, compared to conventional video conferencing systems that do not preserve directional cues between distant sites. Nguyen et al. [20], for example, investigated the effects of preserving directional cues using MultiView (i.e., a "spatially faithful" video conferencing system) and found that those cues help improve the trust formation process between distance-separated members. Werkhoven et al. [33] studied the effects of preserving directional cues by comparing discussions under isotropic and non-isotropic video conferencing conditions and determined that persuasive force is significantly stronger under the isotropic condition.

Researchers have also investigated the effects of supporting directional cues on member's speech patterns. Sellen [27] was the first to examine the effects of supporting directional cues on turn-taking behaviors in four-person conversations using Hydra, although few objective benefits were found. Vertegaal et al. [32] also examined supporting directional cues on triadic conversations using a Hydra-like isotropic system. In their study, they found a positive correlation between the amount of gaze conveyed and the number of turns taken during conversations.

Seating Position

While the importance of directional cues in various group activities is well-established, the directional cues themselves are strongly affected by the seating arrangements of the participants. For instance, a speaker is more likely to gaze at a person sitting across from her than a person sitting beside her.

Previous studies have significantly demonstrated the effects of seating position on group discussions in face-to-face settings. A well-known study on seating position on member speech patterns argues that the person more visible to the current speaker (i.e., the person sitting directly across from the speaker) has a significant tendency to speak next, while those sitting beside the speaker tend to remain silent [29].

Not only does seating position affect the speech patterns between discussion members, but it also affects their psychological states. For example, Sommer [28] reported that competing persons sitting across from each other tend to become more argumentative, while sitting side-by-side tends to reduce antagonism. Excessive eye contact by sitting across from each other is sometimes perceived aggressively, exacerbating antagonism [8].

Regardless whether seating position strongly impacts (small) group discussions, to date no research has proposed a system that supports group-to-group meetings that allow various seating positions among distant parties or empirically examined the effects of changing seating positions on video-mediated communications.

CURRENT STUDY

Using a system called "t-Room," the current study investigates the effects of altering seating positions on video-mediated communication by comparing four-person group communication in two different seating positions in which distant parties sit: (a) across from each other and (b) side-by-side (Figure 1).

Video System: t-Room

t-Room is a room-sharing video system that uses multiple cameras, screens, and speakers to support group-to-group conferencing. The system allows people to take arbitrary seating positions across distant sites, just as in face-to-face meetings.

Video cameras and displays are configured to maintain spatial relationships between distant sites. Similarly, microphones and loudspeakers are configured to maintain the spatial localization of speakers across distant sites; sounds are localized to support selective listening.

Hardware Design of t-Room System

Figure 2 shows the hardware design of the t-Room system. A single t-Room consists of six building modules called monoliths arranged octagonally and a rectangle table at the center[1].

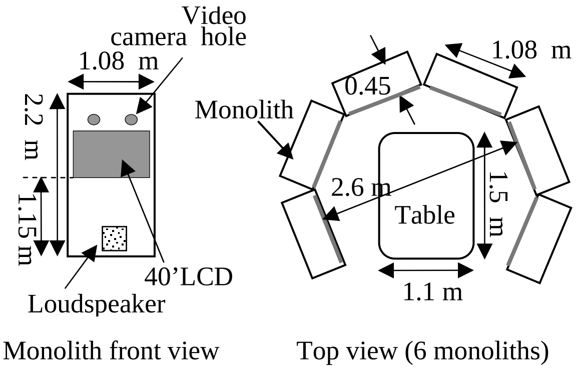

Figure 2 Hardware design of t-Room.

Each monolith consists of a 40-inch LCD panel (1280 by 768 resolution, i.e., WXGA), a HDV camera, and a loudspeaker. A camera is located above each LCD panel and captures the heads and upper bodies of the users inside the room. A polarized film is placed over each camera to eliminate infinite video feedback. LCD panels are positioned at the height of the user heads and upper bodies, showing remote user images, as in Figure 3. The audio channels are full duplex.

Figure 3 Group meeting using t-Room.

The configuration of the video and audio setting in t-Room resembles Hydra. Notable differences include image sizes and camera position; t-Room provides life-size images and places a camera above the screen, while Hydra provides a small image and places a camera below each screen. These differences are supported by prior research: Buxton found that life-size images enhance telepresence [3], and Kenyon et al. reported that the positions of people who appear to look downward are better than others [16].

t-Room and Directional Cues

In this section, we discuss how directional cues are conveyed across distant t-Rooms to support various seating arrangements.

Even though t-Room's configuration (layout) resembles Hydra, these two systems are designed to support different forms of meetings. Hydra supports multiple single-participant sites, while t-Room supports multiple sites with groups as well as individuals at each site.

Such differences introduce a significant gaze information effect across distant sites. When multiple people view a single-view screen, as in t-Room, they share the same perspective taken from a single camera, i.e., a "perspective invariance" that results in the "Mona Lisa Effect" and complicates directionality between different sites. Hydra tackles the problem by providing each person with his/her own setup.

Although t-Room introduces perspective invariance, the system minimizes this problem by sharing all the "who" and "where" information inside the rooms. For example, consider the case where three people are having a discussion in a t-Room in Figure 4.

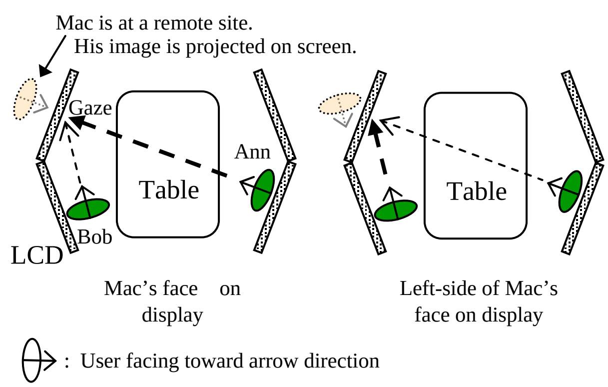

Figure 4 Gaze awareness of a person in remote t-Room.

Suppose Bob and Ann are at the same location, i.e., in the same t-Room. Mac, who is at a distant site, is projected on the left screen beside Bob, and Ann is sitting across from Mac. When Mac is looking at Ann, the front of his face will be projected on the screen. Due to the Mona Lisa Effect, not only Ann but Bob might also feel that Mac is looking at them. However, since Bob knows that Ann is in front of Mac, he notices that Mac is not looking at him, but at Ann. Similarly, when Mac is looking at Bob, the left-side of his face is projected on the screen. This time, neither Bob nor

[1] The central table was designed to share digital documents and real objects on the tables in distant sites (four LCD displays were embedded in the table), although we did not make use of the function in this study.

Ann feel Mac's eyes. However, since Bob knows that no one or nothing else but he is beside Mac, he notices that Mac is looking at him.

Indeed, through our demonstrations of t-Room with more than 600 people, we found that most people correctly recognized the directionality of conversation (i.e., who is talking to whom) when people in the same room stood sufficiently apart from each other. When there is more than one monolith between individuals, they can immediately infer the correct directionality of conversation. However, when people stood close to each other, they tended to misrecognize the directions and required time to learn the correct directions. Such adaptation evokes Dourish et al.'s observations that people's understanding of visual cues in Media Space evolved over time [5]: from initial confusion, through simulated eye contact, and then to the use of gaze awareness.

Hypotheses

We use quantitative and qualitative data analysis to examine three hypotheses:

H1-a (Overall Speaker Switching): In arrangement (a), speaker switches will occur more frequently between distance-separated participants than between co-located participants. In contrast, in arrangement (b), speaker switches will occur more evenly between distance-separated participants and co-located participants.

This hypothesis is based on Steinzor's finding that the person, who is sitting in a position that increases her chances of receiving more gaze attention from the speaker (i.e., the person sitting opposite the previous speaker), tends to speak next [29]. Since the amount of gaze conveyed by a speaker is positively correlated with the number of speaker switches in video-mediated conversations [32], we expect that Steinzor's findings will also hold true for our experimental settings. We expect that speaker switches will be more evenly distributed in arrangement (b), since one of the participants sitting opposite is substituted for a local participant.

H1-b (Speaker Switching Without Explicit Indication of Next Speaker): The speaker switch patterns hypothesized in *H1-a* will be more notable where the previous speaker does not explicitly indicate the next speaker.

While speaker switches are affected by directional cues, speaker switches are fundamentally based on conversational content [21]; a speaker often indicates the next speaker based on conversational content. We expect that speaker switches, where the previous speaker does *not* explicitly indicate the next speaker, will be more amenable to seating arrangements.

In sum, we hypothesized in *H1* that collocated and distance-separated participants will contribute to a conversation more evenly in condition (b) than (a). In such a conversation, we further expect that participants will feel fewer differences between collocated and distance-separated and less likely to form feelings of in-groups and out-groups based on location, leading to sharing a stronger sense of unity:

H2 (Sense of Unity): Participants will feel more separated based on location in arrangement (a) than (b). Conversely, participants will share a greater sense of unity in arrangement (b) than (a).

This hypothesis is also explicable from previous research; Sommer's finding that sitting side-by-side is associated with cooperative orientations and sitting across from each other is associated with competitive orientations [28].

Last, we expect that participants will tend to share their objections with others, rather than keeping them to themselves, when they contribute to a conversation more evenly (i.e., *H1*) and share a higher sense of unity (i.e., *H2*). We expect that such conversations will lead to higher satisfaction with their group solution.

H3 (Quality of Group Solution): Distance-separated participants will develop more similar opinions on the discussion topic in arrangement (b) than (a). As a whole, participants will be more satisfied with the group solution in arrangement (b) than (a).

This hypothesis can also be derived from Werkhoven's finding that persuasive force is significantly stronger when directional cues are conveyed [33]; since t-Room conveys directional cues more correctly when co-located participants sit apart from each other, we expect that participants will be more convinced by remote participants in arrangement (b), leading them to have more similar opinions during discussion and be more satisfied with the group solution than (a).

METHOD

Experimental Design

In this study, four-person groups participated in two consensus-building discussions with different seating positions (see Figure 1): (a) two people in the same location sitting side-by-side and (b) two people in the same location sitting across from each other. The order of seating positions was counterbalanced across participants. The design formed a simple one-factor repeated measures design, comparing discussions in two seating positions.

Task

As a discussion topic, we chose the "desert survival task" [18] that is widely used for training group development. In this task, participants imagine that their airplane has crashed in a desert. Several items have been recovered from the wreckage, and each participant is asked to rank the items for importance to survival. The original problem contained twelve items, which we randomly divided into two sets consisting of six items for different seating positions.

Apparatus

We placed a curtain on the screen walls where participants do not appear to simulate a meeting in a conventional video conferencing system using t-Room (Figure 5). The distance between two (local) persons was approximately 0.9 meters when they sat side-by-side, 1.8 meters when seated across the table, and 2.0 meters when seated diagonally.

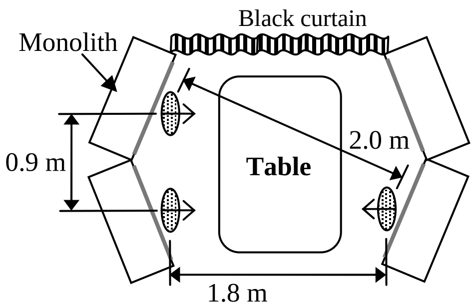

Figure 5 t-Room's experimental setup.

Experimental Condition

We installed two identical t-Rooms in the cities of Atsugi and Kyoto, which are approximately 150 miles apart. The two rooms are connected by FTTH, a commercially available 100 Mbps optical fiber line. The network delay for video and audio transmission between the two cities is around 0.7–0.8 and 0.4-0.5 seconds, respectively. In this study, audio and video were not synchronized, and lip synchronization was not maintained.

Procedure

Procedure (1): On arrival, participants in the same group were placed in separate rooms so that participants at the same location did not get acquainted before the experiment. Next they completed experimental consent forms, moved to the t-Room where they sat in pre-determined positions and were introduced to each other.

Procedure (2): The following procedure was repeated two times with different seating arrangements: Participants were given approximately five minutes to rank the six items of the desert survival task by themselves and to write down their solutions. Next, participants were given approximately 20 minutes to generate a group solution. After a group solution was determined, participants were separated and asked to rank their second individual rankings to determine the possible influence of the group discussion. They also completed post-task questionnaires about the conversations they had just experienced.

Procedure (3): Following the completion of the two tasks, participants completed a final questionnaire about the differences in seating positions. Finally, participants in Kyoto were interviewed about the differences in their discussions between the two seating positions.

Participants

Nine groups of four adults (22 males, 14 females) took part in the experiment. None of the participants knew each other or were familiar with the desert survival task. They had also never used a video-mediated communication system before the experiment. Participants were paid for their participation.

Measures

Video and Audio Recordings. Conversations were video-taped using two DV recorders. Each recorder was located near the entrance of each t-Room to capture the view of the participants in the room. Speech data were transcribed from the DV recordings to analyze speaker switching, and video data were used for more detailed analysis of nonverbal cues.

Speaker Switching. A speaker switch occurs when one person loses the floor and another person gains it without being interrupted for at least 1.5 seconds [27]. Backchannels, laughter, and cross-talk are differentiated from speaker switching [27]. To analyze the impact of seating positions on speaker switching, we counted the numbers of speaker switches between distance-separated and co-located participants.

Quality of Group Solution. The quality of a group solution is measured by calculating the average correlation between each participant's second individual ranking and the group solution [33]. High correlation indicates high satisfaction and low correlation indicates low satisfaction.

Questionnaire. In the post-task questionnaires, participants were mainly asked about their sense of unity in each seating position (e.g., whether they felt separated from the distant participants, whether they felt as if they were all in the same room). Responses reflected a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaires also asked about their satisfaction level of each discussion and the ease of building consensus. In the final questionnaire, participants were asked broader questions about the technology and their preference of seating positions.

Interview. At the end of the experiment, we separately interviewed the participants and asked about their impressions of other participants and the differences they noted as their seating positions changed. These interviews also helped explain some observed events during discussions and to guide further research.

RESULTS

One group was excluded from analysis since the members generated their group solution by a majority vote.

Speaker Switching

We first examined the effects of seating position on overall speaker switches between distant sites. Then we focused on speaker switches that occurred without explicit indication of the next speaker and examined the effects of seating position on them.

Overall Speaker Switching

We expected in *H1-a* that speaker switches would occur more frequently between distance-separated participants than between co-located participants in arrangement (a) than (b).

To verify our expectations, we counted the number of speaker switches between distance-separated and co-located participants in each discussion. Figure 6 shows the average proportion of such speaker switches for each seating arrangement.

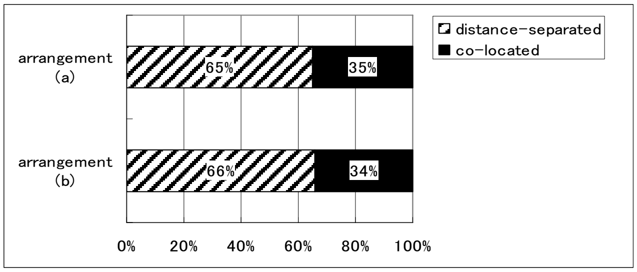

Figure 6 Average proportion of speaker switches between distance-separated and co-located participants.

In both seating arrangements, speaker switches between distance-separated participants comprised a larger proportion of speaker switches than co-located participants. However, note that the most even speaker switching percentage between distant sites is 66.6%, since there are twice as many combinations between distance-separated participants as co-located participants.

The proportion of speaker switches between distance-separated participants was compared between two seating arrangements: 65% (SD=5%) in arrangement (a) and 66% (SD=12%) in arrangement (b). Contrary to our expectations, a two-tailed paired t-test did not find a significant difference between the two seating arrangements.

Overall, speaker switches occurred evenly between distance-separated and co-located participants in both seating positions.

Speaker Switching Without Indication of Next Speaker

Regardless of the seating arrangements in our experiment, a person who led the discussion (i.e., leader) emerged in each group. The leader managed the discussion and often indicated who should speak next based on the conversational content.

Based on Sacks's turn-taking systematics [25], we identified four techniques used by speakers to *verbally* indicate who should speak next: 1) naming the next speaker; 2) asking such a reduced question as "where?" or "who?"; 3) confirming such a previous utterance as "a rain coat?"; 4) producing the first pair-part of an adjacency pair (e.g., asking a question) relevant to certain participants. For example, if only one person previously suggested that a coat is more important than a knife, the question "you think a coat is more important than a knife?" automatically indicates the 'you' being referred to, thus indicating who should speak next.

To examine *H1-b*, which suggested that speaker switching would be affected by seating arrangements, especially when the previous speaker does not explicitly indicate the next speaker, we classified speaker switches in each seating arrangement into two categories based on the above verbal indications: those with/without explicit (verbal) indication of the next speaker.

An average of 22% and 18% of speaker switches were classified as "those without explicit indication of the next speaker" in arrangements (a) and (b), respectively. Within these speaker switches, we calculated the average proportion of speaker switches between distance-separated and co-located participants for each seating arrangement (Figure 7).

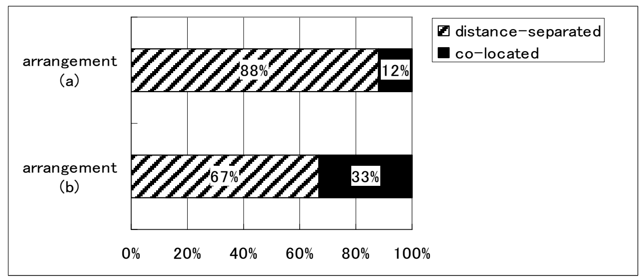

Figure 7 Proportion of speaker switches (without verbal indication of next speaker) between distance-separated and co-located participants.

As expected, without any verbal indication of the next speaker, speaker switches occurred more frequently between distance-separated participants in arrangement (a) than (b): 88% (SD=11%) in arrangement (a); 67% (SD=18%) in arrangement (b). A two-tailed paired t-test found a significant difference between the two seating arrangements ($t(7)=-3.6$, $p<.01$).

It appears that speaker switches occur more evenly between distance-separated and co-located participants in seating arrangement (b) than arrangement (a), when there is no verbal indication of the next speaker.

Although the impact of seating arrangement on speaker switching was limited to places without indication of the next speaker, several participants noticed the difference. When asked about their feelings of separateness between distant sites in each seating arrangement in the post-task interviews, a couple of participants mentioned that they felt that participants spoke more evenly across remote sites in arrangements (b) than (a).

Sense of Unity

Post-task ratings for "participant sense of community", "sense of affinity toward distance-separated participants", "sense of sharing the same room with distance-separated participants", and "psychological distance with distance-separated participants" were used to measure the impact of seating arrangements on participant sense of unity across distant sites.

Since the post-task ratings of these scales were highly correlated (Pearson's coefficient r=.81), scores were averaged into one scale: "sense of unity." Figure 8 shows the mean ratings of participants' sense of unity.

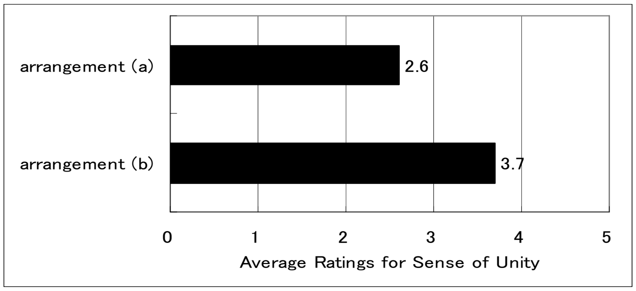

Figure 8 Ratings for sense of unity by seating condition: 1= completely separated based on differences in sites; 5= completely unified with team.

As predicted in *H2*, participants felt more united in arrangement (b) than (a). Mean ratings were 2.6 (SD=1.1) and 3.7 (SD=1.0) for arrangements (a) and (b), respectively. A two-tailed paired t-test found a significant difference between the two seating arrangements: (t(31)=-2.74, p=.01).

Consistent with the questionnaire results, many participants mentioned in the post-experimental interviews that they felt more united when distant participants sat across the table. For example, one participant commented:

> In condition (a), I felt that we were separated into two teams. It was like two interviewers sitting in front of us, and we were being interviewed. In condition (b), I felt that all members were equal and worked together as a team to solve the problem.

Quality of Group Conclusion

To examine *H3*, whether distance-separated participants develop more similar opinions on the discussion topic in arrangement (b) than (a), we calculated the average correlation (Spearman's coefficient) between the second individual rankings of the distance-separated participants in each seating arrangement and compared them using the Wilcoxen test.

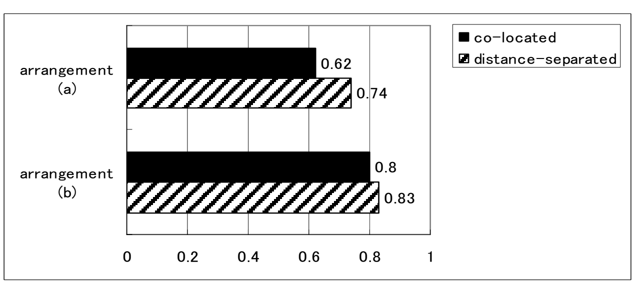

Figure 9 Average correlation of opinions (rankings) between distance-separated and co-located participants.

As shown in Figure 9, the average correlation of the second individual rankings between distance-separated participants was slightly higher in arrangement (b) than (a): ($r_{(b)}$=0.83 vs. $r_{(a)}$=0.74; Z=-1.95, p=.051). Although we had no a priori hypotheses regarding co-located participants, we found that the average correlation of the second individual rankings between co-located participants was significantly higher in arrangement (b) than (a): ($r_{(b)}$=0.80 vs. $r_{(a)}$=0.62; Z=-2.11, p<.05).

Subsequently, we compared the quality of group conclusions between two seating arrangements by calculating the average correlation between each participant's second individual ranking and the group solution. Results showed that the quality of group conclusion was significantly higher in arrangement (b) than (a): ($r_{(b)}$=0.82 vs. $r_{(a)}$=0.71; Z=-3.01, p<.01).

It appears that participants developed more similar opinions on the discussion topic in arrangement (b) than (a), resulting in slightly higher satisfaction with the group solution.

DISCUSSION

In summary, our results show that seating arrangements exerted an important influence on video-mediated conversations. From our experiment that compared four-person group communication in two different seating positions (c.f., distant parties seated across from each other vs. distant parties seated side-by-side), we found the following in the latter seating arrangement: (1) without verbal indication of the next speaker, speaker switches were more evenly distributed between distance-separated and co-located participants; (2) participants shared a greater sense of unity; (3) participants reached a slightly better group solution.

To better understand how seating arrangements exerted such an influence on video-mediated conversations, we analyzed the video recordings of our experiment more closely. First we analyzed how seating arrangements influenced the participant use of nonverbal cues, particularly body orientations and head behaviors; then we discuss how such use of nonverbal cues affected speech patterns, sense of unity, and the quality of group solutions.

Body Orientation and Head Turning

While reviewing the video recordings of our experiment, we realized several notable differences in participant body orientations and head movements between the two seating arrangements.

Arrangement (a): Participants typically sat straight at the table, facing the front screens that showed the remote participants. Their head movements were subtle and rather infrequent; they often stared at the front screens, and head turns toward co-located participants were scarce. Even when asking such questions as "any ideas?" or "Folks, what do you think?" they tended to gaze only at the front screens.

Arrangement (b): Participants tended to greatly tilt their bodies toward the center of the table, as if sitting in front of a round table. Their head movements were larger and more frequent compared to arrangement (a). Furthermore, their head directions (or focus of attention) seemed more evenly distributed between the co-located and distant participants. When asking a question to everyone, they seemed to pass their gaze toward others more evenly.

Body Orientation

To quantitatively measure the differences of body orientations between the two seating arrangements, two coders checked the video recordings at the end of each discussion and assessed each participant's angle of regard in a 10-point scale ranging from 0° (directly facing the table) to 90° (sitting sideways). The assessed values of the two coders were highly correlated (r=.93), and thus the two values were averaged into one.

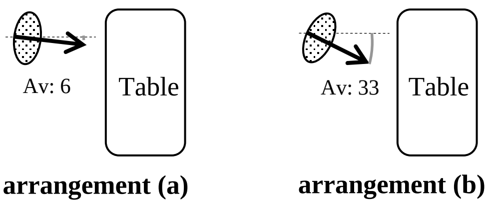

Figure 10 Body orientation by seating condition.

Figure 10 shows the mean angle of regards (i.e., how much the participants tilted their bodies toward the center of the table) in each seating arrangement. We compared participants' angle of regards between the two seating arrangements using a two-tailed paired t-test. Analysis results indicated that participants' angle of regards significantly differed: ($M_{(a)}$=6, $SD_{(a)}$=10; $M_{(b)}$=33, $SD_{(b)}$=15; t(31)=-9.12, p<.001). Participants in arrangement (a) tended to sit straight at the table, while participants in arrangement (b) tended to tilt their bodies toward the center of the table.

Since we did not give participants any directions about their body orientations, we infer that the configuration of the t-Room system *afforded* [7] the participants to change their body orientations. Since remote participants are displayed on 2-dimensional screens, a participant in arrangement (b) will completely lose sight of the remote participant seated beside him, unless he tilts his body toward the adjacent screen (i.e., center of the table). Indeed, in the post-experimental interviews several participants mentioned that they initially had trouble viewing the remote participant seated beside them, so they changed their body orientations.

Head Turning Direction

Since participant body orientations differed significantly between the two seating arrangements, we inferred that participant head directions differ accordingly [26].

To determine whether the proportion of head turns directed toward distant participants differed between seating arrangements, we classified participant head turns into two categories: to a distant participant or a co-located participant. Two coders classified the head turns by viewing the video recordings[2] after first classifying the head turns of a common video recording to confirm that their coding reached high agreement (96%). They then divided the rest of the video recordings and each classified different video recordings.

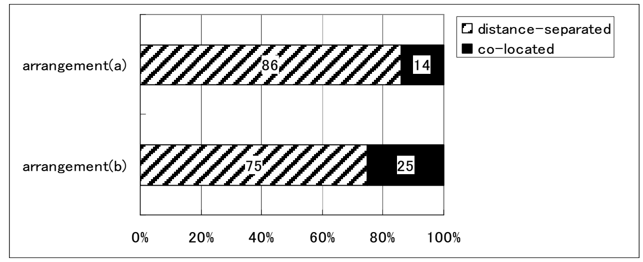

Figure 11 Mean percentage of head turns directed toward distant and co-located participants in each seating condition.

Figure 11 shows the mean proportion of participant head turns directed toward distant and co-located participants in each seating arrangement. We compared the proportion of participant head turns directed toward distant participants between two seating arrangements using a two-tailed paired t-test. Analysis results indicated that participants tended to turn their heads significantly more toward the co-located participant in arrangement (b) than (a): ($M_{(a)}$=14%, $SD_{(a)}$=20%, $M_{(b)}$=25%, $SD_{(b)}$=23%; t(31)=-8.24, p<.001).

Interpretation of our Findings

The body orientations and head movements of the participants in our study differed significantly between the two seating arrangements. We infer that these differences account for much of our study's findings.

Speaker Switching

Regarding speaker switching, the leaders basically managed the discussions and often indicated who should speak next based on the conversational content in both seating arrangements. Changes in seating arrangements did not alter the overall speaker switching patterns between sites. However, as expected, seating arrangements significantly influenced speaker switching at points without verbal indication of the next speaker. By exclusively limiting our focus to these speaker switches, we found out that speaker switches in arrangement (b) were more evenly distributed between co-located and distance-separated participants than in arrangement (a).

The result can be explained by the fact that participants turned their heads (or gazed) more at co-located participants in arrangement (b) than (a). Co-located participants in arrangement (a) were seated side-by-side and had little opportunity to make eye-contact with each other, whereas

[2] During discussions, most participants looked down at the items on a sheet of paper. They sometimes lifted their heads up to glance at a speaker or other participants.

co-located participants in arrangement (b) were seated across the table and had more chances. Since the amount of gaze is positively correlated with the number of speaker switches [14], speaker switches between co-located participants were more frequent in arrangement (b). Furthermore, we infer that speaker switches between co-located participants did not dominate the overall speaker switches in arrangement (b) because the participants tilted their bodies and did not directly face each other.

Such an influence of seating arrangement on overall speaker switching was not visible, probably because most speaker switches were organized along conversational content, and those less organized (i.e., without indication of the next speaker) constitute only a small part of the speaker switches in the conversations (approx. 20%).

Sense of Unity

Participants in our experiment felt more united when they were seated in arrangement (b) than (a). Such feelings may be relevant to their angle of regards; in arrangement (b), participants tilted their bodies and sat as if in front of a round table. Although such an adjustment of participant body orientations may be afforded by the constraints of the t-Room system (i.e. layout of the displays), the adjustment of their body orientations led them to constitute the F-formation [15], representing that they belong to the same group.

Another possible reason for the differences in their sense of unity lies in the differences of speaker switches between seating arrangements. The speaker switching pattern found in arrangement (a) (e.g., distant participants answering anonymous questions) resembles the speaker switching patterns of telephone conversations, which exacerbate psychological distances based on location [30]. In contrast, speaker switches are evenly distributed in arrangement (b), and thus feelings of remoteness may be reduced.

Quality of Group Solution

The co-located participants in our study developed more similar opinions on the discussion topic in arrangement (b) than (a). This may be explained by the fact that a persuasive force is generally stronger when the listener sits across from rather than beside the speaker [8].

Distance-separated participants also developed similar opinions slightly more often in arrangement (b) than (a). We infer that this result stems from the fact that participants can assess the directionality of conversations more correctly in arrangement (b) than (a); in arrangement (b), larger head turns are afforded by the constraints of the t-Room system (i.e. two screens showing remote participants are placed sufficiently apart from each other), and such large differences in head directions can easily be detected by distant participants. Since people are generally more convinced by others when directional cues are conveyed properly [33], participants in arrangement (b) were more convinced by distant participants, resulting in higher correlation of opinions between distance-separated participants.

A higher correlation of opinions between co-located and distance-separated participants resulted in higher satisfaction of the group solution in arrangement (b).

CONCLUSION AND DESIGN IMPLICATIONS

Our results demonstrate that seating arrangements exert an important influence on video-mediated conversations; different seating arrangements yielded differences in speech patterns, senses of unity, and quality of solutions. From further analysis, the system configuration (display layout) allowed the participants to change their body orientations and head movements in differing seating arrangements, creating different patterns of video-mediated conversations. Specifically, (1) a display (showing a distant participant) placed beside a participant afforded the participants to orient their bodies toward the screen; (2) displays (showing distant participants) placed sufficiently apart from each other allowed the participants to greatly turn their heads between them. Since such changes in people's use of nonverbal cues strongly affected (video-mediated) conversations, we speculate that similar effects would be achieved by altering the allocation of the display layouts. Video systems that allow group-to-group meetings should consider the effects of such factors; displays must be allocated so that the layout allows people to orient their bodies and turn their heads in an expected way. Furthermore, it is preferable to provide people with various seating arrangements or/and the flexibility to change the display layouts, since the optimal pattern of conversations varies with different activities.

Not only the display layout but also camera positions/angles influence group discussions [13]. Further investigation is required on how the combinations of these factors affect group discussions. We also need to investigate whether seating positions exert the same influence on people who are well-acquainted with each other, since group-to-group meetings typically occur among such people. Furthermore, we will investigate how people choose their seating positions and change their body orientations dynamically as group activities proceed.

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