Meeting Mediator: Enhancing Group Collaboration with Sociometric Feedback

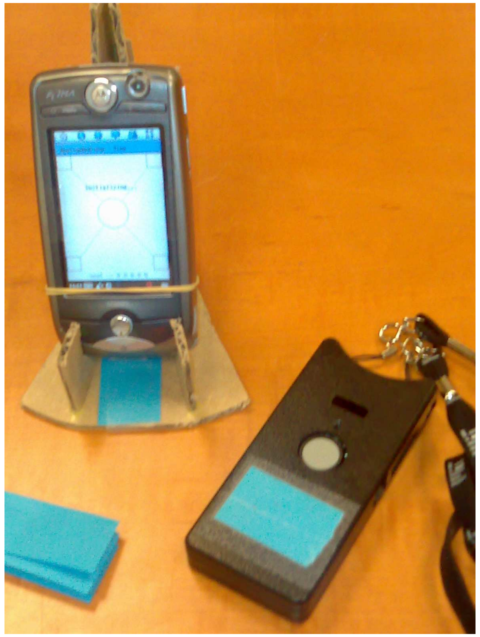

figure 1. The Meeting Mediator: Sociometric badges (right bottom) capture group dynamics which is displayed as real-time feedback on mobile phones (left top).

Taemie J. Kim
MIT Media Laboratory
20 Ames St. E15-386
Cambridge, MA, 02139 USA
taemie@media.mit.edu

Agnes Chang
MIT Media Laboratory
20 Ames St. E15-383
Cambridge, MA, 02139 USA
achang@media.mit.edu

Lindsey Holland
MIT
77 Massachusetts Ave.
Cambridge, MA, 02139 USA
lholland@mit.edu

Alex (Sandy) Pentland
MIT Media Laboratory
20 Ames St. E15-384
Cambridge, MA, 02139 USA
pentland@media.mit.edu

CHI 2008, April 5 – April 10, 2008, Florence, Italy
ACM 1-xxxxxxxxxxxxxxxxxx.

Abstract

In this paper we present the Meeting Mediator (MM), a real-time, personal, and portable system providing feedback to enhance group collaboration. Social interactions are captured using Sociometric badges [6] and are visualized on mobile phones to promote change in behavior. In a study on brainstorming and problem-solving meetings, MM had a significant effect on overlapping speaking time and interactivity level without distracting the subjects. Our system encourages effective group dynamics that may lead to higher performance and satisfaction. We envision MM to be deployed in real-world organizations to improve interactions across various group collaboration contexts.

Keywords

CSCW, Social visualization, Meeting support, Sociometric sensors

ACM Classification Keywords

H.5.3 Group and Organization Interfaces: *Computer-supported cooperative work*

Introduction & Related Work

Social scientists have long been interested in small group collaboration, trying to answer questions such as: What are the characteristics of effective groups? What can be done to improve the quality of group communication? Group dynamics refer to the activities, processes, operations, changes, interdependencies, and interrelationships that transpire in social groups [4]. Traditionally, sociologists have employed human observers or surveys to understand group dynamics, but data acquired by these methods are inevitably subjective and not in micro-scale or real-time. Thus, there are efforts to use computational methods to understand group dynamics. DiMicco et al. used microphones to detect participants' speaking time and visualized the information in real-time on a large shared display. However, this system only captures speaking time, which is just one relevant feature of social interaction. Furthermore, public displays are not optimal since they cannot always be available for ad-hoc meetings, and their public nature can cause discomfort to users [3].

To address these limitations, we created the Meeting Mediator (MM), a system which provides real-time feedback on group dynamics data collected by Sociometric badges [6]. The badge can collect unbiased and richer data than traditional methods by sensing body movement, proximity to other badges, and speaking characteristics such as speed and tone of voice. By visualizing this data in real-time on the mobile phone of each user, our system is able to encourage positive changes in group collaboration patterns. The prompt, portable, and personal qualities of MM allow it to detect and support impromptu encounters around the water cooler just as well as preplanned gatherings in the conference room.

In the following sections we describe the MM system in further detail and present the findings from a controlled study evaluating the effect of MM feedback on group dynamics in different meeting situations.

System Description

Sociometric badges

The Sociometric badge (figure 1) designed at the MIT Media Lab Human Dynamics group [6] is an electronic sensing device that collects and analyzes human behavioral data. Its current capabilities include:

- Measuring body movement using a single 3-axis accelerometer. This can detect activities such as gestures, walking, and sitting.
- Extracting speech features in real-time to measure non-linguistic social signals. The badge does not record content, but is capable of identifying social signals such as interest, persuasiveness [7] and signs of stress [9].
- Sending and receiving information over 2.4GHz radio to and from different users and base stations for real-time communication. It can also capture proximity data which can be used to detect group gatherings.
- Performing indoor user localization by measuring received signal strength from fixed based stations.
- Capturing and identifying face-to-face interaction time using an IR sensor.
- Communicating with Bluetooth enabled mobile devices such as mobile phones or Bluetooth headsets.

In organizations, group collaborations are not all pre-planned: groups of varying sizes and lengths are dynamically formed. Sociometric badges can detect these various meetings and autonomously provide real-time feedback. However, for the purpose of this paper we examine the effect of MM on meeting dynamics by conducting a controlled study where the number of participants was fixed and the participants were all co-present for the full duration of the meeting. Thus we

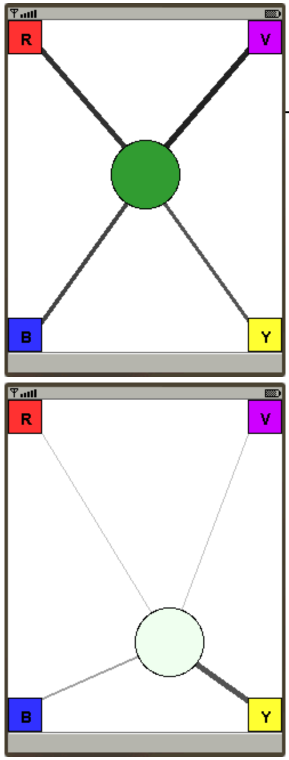

figure 2. The visualization on the phone can display effective group dynamics (top) and non-effective group dynamics (bottom). Circle color denotes group interactivity level, circle position denotes balance in participation, and line thickness denotes speaking time.

analyze only the speech and body movement data from the Sociometric badge to detect collaboration dynamics.

Visualization on mobile phones

MM's mobile phone application was developed for J2ME-enabled smart phones. Each participant is provided with one mobile phone and one Sociometric badge that are paired via Bluetooth. The four badges communicate their wearer's speaking and movement status to each other over the 2.4GHz radio.

The phone visualization was designed to be a persuasive and ambient interface, encouraging participants to change their behavior in a direction beneficial to group collaboration. Each of the four participants is represented as colored squares in the corners of the screen (figure 2). In the user study, the square colors were identical to the color of each participant's badge and seat. The color of the central circle gradually shifts between white and green to encourage interactivity, with green corresponding to a higher interactivity level. Balance in participation is displayed through the circle's location: the analogy is such that the more a participant talks the stronger they are pulling the circle closer to their corner. We promote speech by displaying each member's speaking time through the thickness of the line connecting the center circle with each member's corner. The visualization is updated every 5 seconds and is re-initialized every time a new meeting session starts.

We designed the interface to be in the periphery of the user's attention. All changes on the display are made gradually so that it does not require constant attention from the user. Also, text and small details were purposefully avoided so that a mere glimpse would be sufficient for information retrieval.

Theory and Hypotheses

Management science has identified the most common collaboration challenges to be social loafing (individuals making less effort in groups), production blocking (over-participators monopolizing the floor), and incomplete information exchange [1,2]. We believe that MM can address these challenges by effecting change in individual and group behavior. For the scope of this paper, we focus on three main effects of MM on group dynamics and the following hypotheses were posed:

H1. People with MM speak more

We hypothesize that MM will encourage meeting participants to modify their behavior to speak more. To detect this, we examine the speaking time of each participant. We define *total speaking time* as the total amount of time an individual was speaking, regardless of interruptions or overlap speech from others, and *solo speaking time* as the amount of time an individual was the only participant in the group speaking.

H2. People with MM will be more interactive

We posit that participants using MM will be more interactive. We identify high levels of interactivity through an increased amount of turn-taking and shorter speech segment length. We define a *turn* as each instance a participant takes over a conversation either from another participant or from silence. Next, we define a *speech segment* as any one continuous stream of speech from an individual, regardless of interruption or overlap from other participants.

H3. MM'S PHONE INTERFACE IS NOT DISTRACTING
We hypothesize that MM, as an ambient and personal display, will not be disruptive to the purpose of the meeting. We use post-task surveys and bodily stress estimates to predict the distraction level. Stress levels can be estimated through movement energy and its variance [9]. We therefore expect that the movement energy and its variation will not be significantly different between participants with MM and participants without MM. We define *movement energy* as the average amount of body movement over a fixed unit of time, i.e. the amount of gesturing during conversation; and *movement energy variance* as the variation in movement energy, i.e. the abruptness of movement.

Evaluation

We chose to evaluate two meeting types in our experiment, brainstorming and problem-solving, to encompass common meeting purposes.

To evaluate our hypotheses, we conducted a study of 37 groups of four subjects each. Subjects were recruited on a university campus and through public internet message boards and were given monetary compensation for their time. Due to equipment failures in some groups, data from only three subjects per group was analyzed. However due to the interactive nature of collaboration, the behavior of the three members can represent the dynamics of the entire group [8]. The average subject age was 28.2, and the male to female ratio was 54:46. A sociometric badge was provided to all subjects to measure the group dynamics. To verify the effects of MM, we performed a between-subject experiment comparing 18 groups with MM feedback on their mobile phones (experimental condition) to 19 groups without mobile phones (control condition). Each team began with one short practice task for which no score was recorded, and then performed two scored tasks with identical setup.

Task 1
Phase 1: Brainstorming (8 min)
Phase 2: Problem-solving (10min)
--- Post-task questionnaire
Task 2
Phase 1: Brainstorming (8 min)
Phase 2: Problem-solving (10min)
--- Post-task questionnaire

table 1. Experimental procedure

figure 3. The experimental setup: Four subjects participate in brainstorming and problem-solving meetings wearing Sociometric badges.

The task given to subjects was based on a modification of the game "Twenty-Questions," which integrated both brainstorming and problem-solving scenarios [10]. At the beginning of each task each group was given a set of ten yes/no question-and-answer pairs. For the first phase of each task, groups were given 8 minutes to collaboratively brainstorm as many possible solutions that fit the set of question-and-answers. Then, continuing into the second phase, groups were given 10 minutes to ask the remaining ten questions of the Twenty-Question Game to determine the correct solution. Following each task, subjects filled out a post-experiment questionnaire comprised of five-point Likert scale questions regarding their own personality, the group dynamics and each individual's performance for each phase, and if applicable, the utility of the MM

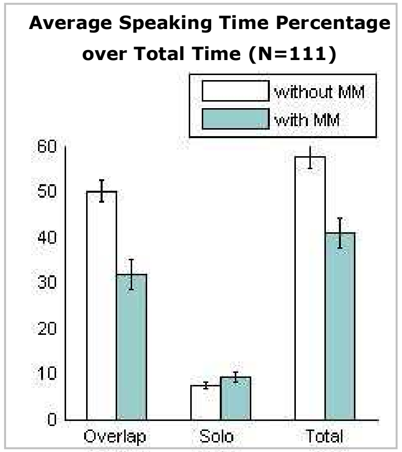

figure 4. Subjects without MM have more overlap speaking time than subjects with MM (50.1%, 31.8% of total time, F=20.9, p<0.0001), same solo speaking time (7.4%, 9.2% of total time, p=.15), and more total speaking time (57.5%, 41.0% of total time, F=3.7, p<.0001).

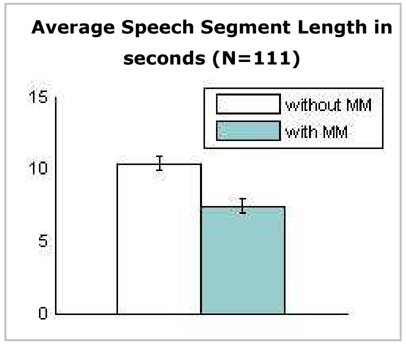

figure 5. Subjects without MM have longer average speech segment length than subjects with MM (10.4sec, 7.4sec of total time, F=18.5, p<.0001).

system (table 1). Performance (i.e. scoring) was determined by (1) the number of correct ideas in the brainstorming phase and (2) the number of questions used to arrive at the correct answer in the problem-solving phase. Goal incentive was provided in the form of gift certificates for the top-scoring team.

Results and Discussion

Effects of MM on Individual Speaking Time (H1)

MM had a very strong effect on speaking dynamics. The primary effect was a dramatic reduction in overlapping conversations. This is in line with our qualitative observation that groups without MM sometimes divided into sub-groups and had separate conversations instead of working as one team. The average overlap speaking time is significantly lower for subjects with MM (mean=31.8% of the total time) than subjects without MM (mean=50.1%, F=20.9, p<.0001, figure 4).

On the other hand, the solo speaking time of the subjects with MM is not significantly different (mean=9.2% of the total time) compared to that of the subjects without MM (mean=7.4%, p=.15, figure 4). However the solo speaking times in problem-solving phases were marginally different (mean= 6.45% without MM, 9.89% with MM, F=3.7, p=.056).

Due to the large difference in overlapping speaking time, the total speaking time was significantly shorter for subjects with MM (mean = 41.0% of the total time) than subjects without MM (mean = 57.5% of the total time) (F=17.0, p<.0001, figure 4). Therefore when subjects were provided with visual feedback through MM, even though they spoke less in total, they were more likely to collaborate with their teammates as one team.

Effects of MM on Group Interactivity Level (H2)

Further analysis of speech gives us new insight to the group interactivity level. Subjects with MM have significantly shorter speech segment lengths (mean = 7.4sec) compared to those without MM (mean =10.4sec, F=18.5, p<.0001, figure 5). This relationship is maintained in both brainstorming and problem-solving phases. This supports H2 in that MM increased the group level of interactivity.

There was no significant effect on the overall number of turns per individual (3.40 turns/min without MM, 3.16 turns/min with MM, F=2.0, p=.16, figure 6). However, subjects with MM have significantly fewer turns in the brainstorming phase (3.37 turns/min without MM, 2.90 turns/min with MM, F=5.9, p=.017) while they have significantly more number of turns in the problem-solving phase (3.03 turns/min without MM, 3.59 turns/min with MM, F=4.1, p=.047). This may be due to the high amount of speech overlap in brainstorming.

Effects of MM on Distraction (H3)

The analysis of movement energy supports H3 indicating that subjects with MM did not display more stress. In fact, there is evidence that subjects with MM exhibited less stress in the brainstorming phase. During the brainstorming phase, their average movement energy had no significant difference compared to that of subjects without MM (mean = 1.25g without MM, 1.28g with MM respectively, F=0.01, p=.70, $g=9.8m/sec^2$) but their movement energy variance was significantly lower (mean=0.049g without MM, 0.0038g with MM respectively, F=7.2, p=.0084). H3 is also true for the problem-solving phase in that MM did not have a significant effect on subjects' stress level. These

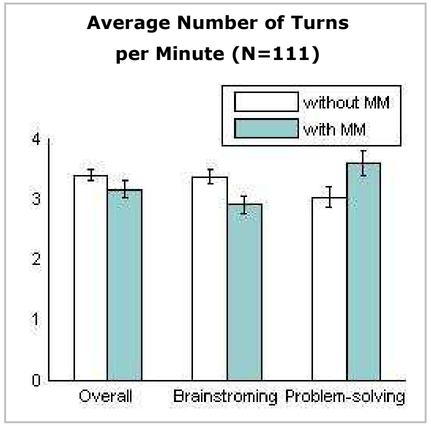

figure 6: The number of turns of subjects without MM is not significantly different from that of subjects with MM (3.40 turns/min without MM, 3.16 turns/min with MM, F=2.0, p=.16). Subjects with out MM have a higher number of turns in brainstorming sessions (3.37 turns/min without MM, 2.90 turns/min with MM, F=5.9, p=.017), but fewer turns during problem-solving (3.03 turns/min without MM, 3.59 turns/min with MM, F=4.1, p=.047).

results are different from those of DiMicco, where subjects felt discomfort due to the public display.

Consistent with these results, findings in the post-task survey data showed no significant difference in the level of distraction (mean = 1.57 without MM, 1.71 with MM on a 5 point Likert scale, F=1.66, p=.20). Also only 48% of the subjects reported that they looked at the phone often during the experiment.

Future Work

We plan to continue analysis on the relationship between group dynamics and performance. During the study, we measured the performance of the group in both the brainstorming and problem-solving phase. We found indications of a very strong interaction effect between MM and group dominance structure, which affects both performance and participation balance.

We also plan to observe distributed collaboration. Hinds and Bailey [5] have demonstrated that distributed collaboration may have very different dynamics and performances compared to co-located collaboration. We plan to use the Sociometric badges to further understand the differences between these two meeting situations. We posit that MM will have a stronger effect on distributed collaboration since many of the lost social signals can be recaptured and communicated through MM.

Conclusion

Meeting Mediator is a mobile system that detects and enhances collaborations in meetings. Our controlled study has shown that it indeed has a significant effect on various aspects of group dynamics while not being a distracting factor for the subjects. MM has improved upon previous work by utilizing Sociometric badges for deeper analysis. Furthermore, rather than designing a custom system for fixed conference rooms, we offer a mobile system that can be easily deployed for diverse types of collaboration.

References

[1] Dennis, A.R. Information exchange and use in group decision making: You can lead a group to information, but you can't make it think. MIS Quarterly 20, 4 (1996), 433-457.

[2] Diehl, M. and Stroebe, W. Productivity loss in brainstorming groups. Journal of Personality and Social Psychology 53, 3 (1987), 497-509.

[3] DiMicco, J.M., Hollenbach, K.J., and Bender, W. Using visualizations to review a group's interaction dynamics. In Extended Abstracts CHI 2006, ACM Press (2006), 706-711.

[4] Forsyth, D.R. *Group Dynamics*, Brooks & Cole, Belmont, MA, USA.

[5] Hinds, P.J. and Bailey, D.E. Out of sight, out of sync: Understanding conflict in distributed teams. Organization Science 14, 6 (2003), 615-632.

[6] Olguin Olguin, D. Sociometric badges: Wearable technology for measuring human behavior. Master's thesis, MIT Media Laboratory, May 2007.

[7] Pentland, A.P. Social dynamics: signals and behavior. In Proc. ICDL 2004, IEEE (2004).

[8] Stolzman, W.T. Toward a social signaling framework: Activity and emphasis in speech. Master's thesis, MIT Media Laboratory, 2006.

[9] Sung, M., and Pentland, A.P. PokerMetrics: Stress and lie detection through non-invasive physiological sensing, Ph.D. thesis, MIT Media Laboratory, 2005.

[10] Wilson, D.S., Timmel, J.J., and Miller, R.M. Cognitive cooperation: when the going gets tough, think as a group. *Human Nature 15*, 3 (2004), 225-250.