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Conflict Resolution in Remote Collaborative Problem Solving: A Comparison of Different Computer Mediated Communication Methods

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Abstract

We compared the effects of text-, audio- and video-based communication methods on how people performed an appointment-scheduling task that involved both a cooperative and a conflict resolution component. The results showed that video-based communication method was more supportive of cooperative tasks when the task difficulty was high, and when there were more inherent conflicts in the task, in which more negotiation was required to resolve the conflicts. As a result, performance difference of the dyad was smaller in video communication. Different patterns of task completion time, problem space visitations and conversation dynamics further supported the effect of communication methods. Results of this study have important implications in understanding the process of collaborative problem solving and conflict resolution when different communication channels were used for remote collaborators.

Keywords: Problem solving; conflict resolution; negotiation; collaboration; computer mediated communication.

Introduction

One common reason for collaborators to communicate is to come up with solutions or methods that are acceptable to both parties. More often than not, conflicts arise. It is critical for collaborators to communicate their needs and constraints to resolve these conflicts, requiring collaborators to engage in negotiation and to obtain a mutual agreement, which may or may not be the best possible solution to both parties. In other words, one party may need to compromise and accept a non-preferred solution that may be *perceived* to be optimal to both parties. Given that the process of conflict resolution often hinges on the effectiveness of the communication, one may expect that the communication channel will play a pivotal role in influencing the final outcome of the conflict resolution. Recent advances in technologies that support computer-mediated communication (CMC), such as various forms of text, audio, and video conferencing, have made remote collaborative work less costly and more feasible. Although intuitive and important, relatively few studies have examined the effectiveness of different CMC methods in supporting the process of conflict resolution during remote collaborative works. (for exceptions, see Cooper & Taleb-Bendiab, 2004; Foroughi, 1998).

The goal of the current study is to compare the effects of three commonly used CMC methods (text, audio and video chatting) on a conflict resolution task. The task aims at testing two major components of remote conflict resolution: During *information exchange*, collaborators need to exchange their needs and constraints to establish common grounds and set up a solution space for both parties; during *negotiation*, collaborators need to decide on a solution that balances the needs and constraints of both parties so that a solution can be selected from the solution space. Our analysis will focus on how different CMC methods impact each stage, and eventually influence final outcomes.

Establishing Common Ground

A prerequisite of conflict resolution is to establish a mutual agreement of the possible solution space (i.e., grounding) (Clark & Brennan, 1991; Newell & Simon, 1972) so that the potential cost-benefit comparison can be made among each solution by each of the collaborators. Therefore, the process through which mutual ground was established during information exchange could have an impact on subsequent negotiation and conflict resolution. Communication methods may influence this process as cost of information exchange may impact how likely people will exchange their needs and constraints. For example, establishing mutual ground might be more difficult in text-based communication due to the higher costs, and collaborators might not be willing to fully examine the problem space to identify and compare possible solutions. As a consequence, negotiation can be less efficient based on an incomplete solution space.

The strategies used to communicate information might also influence how potential solutions are discussed. As a result, the communication method may influence how either party will select and propose potential solutions to the other party to consider, or how they will interpret whether the other party may consider a solution to be acceptable or not. In other words, the communication method may also directly impact the negotiation process, which may lead to suboptimal outcomes for the one or both parties.

Effects of CMC Methods

Studies comparing the effectiveness of CMC methods on collaborative work to the traditional method of face-to-face interaction yielded mixed results (Doherty-Sneddon et al., 1997; Firm, Sellen, & Wilbur, 1997; Fussell & Krauss, 1992; Straus & McGrath, 1994). Collaborators using the video conferencing tend to perform at a similar level as collocated collaborators. However, bandwidth and quality of video/audio streams play a crucial role in how video conferencing can be helpful in supporting collaborative work. Audio-only communication was found to be less effective compared to video conferencing, mainly due to its lack of nonverbal cues such as facial expressions, gesture

and focus of visual attention. Text-based communication is reported to be least effective due to the fact that a large amount of non-textual information in both visual and acoustic format (e.g., speech tones and emotion, etc) cannot be directly conveyed through text-based communication.

Relatively few studies have directly investigated the effects of CMC methods on how collaborators resolve conflicts in remote work environments. Inferences can be made from the nature of conflict resolution tasks and existing evidences of the different features among different communication methods. Conflict resolution is usually a demanding task for several reasons. First, all parties involved in the conflict need to establish mutual ground (Clark & Brennan, 1991; Cramton, 2001; Fussell & Krauss, 1992) such that they are all aware of the solution space involved in the conflict and the potential tradeoffs of each solution to each party. Second, several rounds of conversation exchanges are usually necessary during the negotiation process before a consensus can be reached. Third, non-textural information can be critical in the process of negotiation by providing cues that can be used to make inferences of other parties' preferences and characteristics (e.g., personality, mood, willingness to compromise, etc.) and to make adjustments to strategies of negotiation so that other parties will be persuaded to compromise, thus maximizing individual and group performance.

The Current Study

We were interested in the effects of different CMC methods on the process of information exchange and negotiation during conflict resolution. We chose the task of appointment scheduling in this study for two reasons. First, it is a very common subtask in most remote collaboration that people encounter in their daily lives, and they often play a pivotal role in the success of collaboration. Second, this task involves two stages that are typically found in many remote collaboration tasks: the *information exchange* stage in which the collaborators need to collectively find one or more time slot(s) that both parties are available; and, after mutual ground is established and a potential solution space is obtained, a *negotiation* stage, in which potential solutions are proposed, rejected or accepted, and preferences are expressed and perceived until one solution is eventually accepted by both parties. Although in actual situations these two stages could be intertwined, the two components are essential for successful conflict resolution, and could be subject to changes at different levels of task difficulty (how easily the solution space can be defined) and different levels of conflicts (the amount of overlap between the needs and constraints of the two parties). Thus, we introduced these two independent variables (task difficulty and level of conflict) to systematically examine the effects of CMC methods on the conflict resolution processes. Based on previous findings, we would expect that communication methods with a higher bandwidth would probably be more supportive for participants performing the task in the current study.

Method

A 2 by 2 by 3 mixed design was employed in the current study. Participants were asked to work in pairs, each of which was given a 10-week calendar. Their task was to schedule 2 appointments for each week by communicating with each other via one of the three commonly used *CMC tools* (text, audio or video chatting). A scoring system was introduced to encourage participants to maximize personal scores by scheduling appointments on preferred time slots. We manipulated the *level of difficulty (easy vs. hard)* for each week by putting different score combinations in the solution space. A *level of conflict (low vs. high)* was also introduced to further examine the process of negotiation.

Participants

One hundred and four people participated in the current study. One pair of participants' responses in the text condition and one pair in the audio condition were excluded from the analysis due to technical problems, yielding the final sample size of 100 participants, 17, 16 and 17 pairs in text, audio and video condition, respectively. Participants in the three conditions were similar in age (M = 23.90, 22.97 and 24.13 years, SD = 4.45, 3.25 and 5.15 for text, audio and video condition, respectively, $F_{(2, 97)} = .64$, $p > .05$), gender (16, 13 and 15 males and 18, 19 and 19 females in text, audio and video condition, respectively), education level (college or higher), and their experience of using CMC tools in their everyday life as measured in a questionnaire.

Materials

Forty pairs of weekly calendars were prepared. Each week contained a *problem space* of 40 hours (Monday-Friday, 9AM-5PM). Appointments can only be scheduled on whole hours. A scoring system was introduced in a way that participants could earn 0 to 3 points for each appointment depending on when it was scheduled. To help participants better comprehend the scoring the system, time slots with higher points were explained as more desired for scheduling appointments in real life situations (see Table 1). Color coding was also introduced when visualizing the calendars using Google Calendar (See Figure 1).

Table 1. Scoring system.

Time slot	Color	Points
Available, preferred	White	3
Available, not preferred	Green	2
Not available, event in this slot can be rescheduled with effort	Blue	1
Not available, event in this slot cannot be rescheduled	Red	0

Level of Difficulty. Each week had a 12-hour *solution space*, within which each scheduled appointment would give both sides of the pair a non-zero score. The rest 28 hours were considered non-solutions since at least one side of the pair would get 0 points if an appointment was scheduled in those time slots. The level of difficulty for each

week was manipulated by varying the number of preferred time slots within the solution space (see Table 2). Thus, the 20 easy weeks contained more time slots with higher points, whereas the 20 hard weeks contained more time slots with lower points.

Table 2. Solution space for easy vs. hard weeks.

# of hours		Solution space	
Easy	Hard	Point Combination (calendar 1 – calendar 2)	
1	2	Low	1-1, 1-2, 2-1
1	1	Medium	2-2, 1-3, 3-1
2	1	High	3-3, 3-2, 2-3

Level of Conflict. In order to get participants more engaged and to increase the diversity of possible solutions, several bonus point conditions were introduced (e.g., earning an extra point by avoiding particular hours). After taking all bonus points into account, solutions that would yield the highest total score of the pair were identified. As a result of the introduction of bonus points, the 40 weeks could also be grouped into two groups. In *low-conflict weeks*, only one solution that yielded the highest total score could be identified, thus once such solution was found, neither side of the pair need to compromise. In *high-conflict weeks*, more than one solution that yielded the highest total score could be identified, and each side was able to earn different scores depending on which solution was chosen, thus a process of negotiation was necessary for each side to optimized his/her personal scores.

The level of conflict was not directly manipulated, but identified during the process of examining the solution space of each week. However, the level of conflict was independent of the manipulated level of difficulty since roughly half of the easy weeks (12) and the hard weeks (11) were grouped into low-conflict weeks, and the rest into high-conflict weeks.

Procedure

Participants were seated at computers in different rooms or separated by large barriers that prevented them from seeing each other. Each pair of participants received a 10-week calendar of 5 easy weeks and 5 hard weeks randomly chosen from the calendar pool, in random order. Their task was to schedule two 1-hour appointments on two different days for each week, thus 20 appointments in total. It was emphasized to the participants that their goal was to get their individual score as high as possible, and the three who got the highest individual total scores among all participants would receive an extra $10 as a reward.

Participants communicated with each other using Google talk through text, audio or video chatting and marked their scheduled appointments on a given answer sheet. Chat histories in the text group were saved. Participants in the audio and video groups were asked not to type in the chat box, and their conversations were recorded by screen activity recording software named *SnapzProX*.

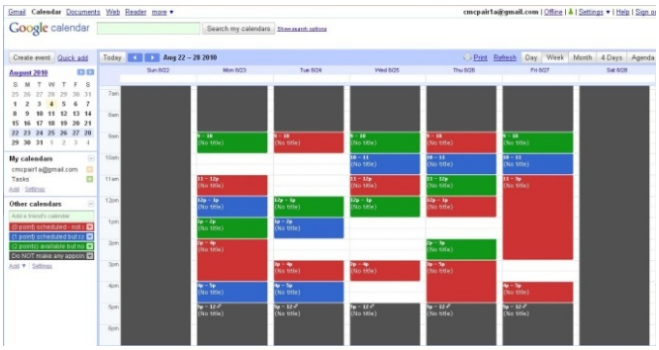

Figure 1. Example calendar of one week.

Measures

Performance. Participants' answer sheets were scored based on the scoring system in Table 1. A participant could earn up to 8 points for one week. Participants' *overall performance* was measured by the sum of the scores of the pair averaged across 10 weeks. Although it was possible that two participants earned the same score, we did not get any tied pairs in this experiment. Therefore, for all pairs in this experiment, there was always one person getting a higher total score than the other. We divided each pair into high- vs. low-performance side. A *difference score* was calculated by subtracting the score of low-performance person from the high-performance person for each week. This difference in performance within each dyad was used not only due to the interdependence in performance within each dyad, but also because this difference score would be more meaningful in measuring the result of negotiation than using individual scores.

Task completion time. The time each pair spent in scheduling appointments for each week was measured. In the cases that they went back to a particular week, the total time spent on that week was calculated. In the cases that they digressed from working on the current scheduling task, the time of digression was deducted. The average time each pair spent on each of the four week types were calculated.

Problem Space. For each week, the number of 1-hour slots participants visited/mentioned during the scheduling process was counted as an indicator of the size of the actually *visited problem space*. The number of 1-hour time slots participants visited/mentioned for more than once was counted as a rough indicator of the size of the *negotiation space* since revisiting a particular time slot was typically associated with comparison of different potential solutions.

Negotiation. Participants' conversations were recorded for text condition and transcribed into text for audio and video conditions. Four native English speakers read the conversations carefully and judged whether each sentence involved negotiation. When a sentence was devoted to evaluating or comparing potential points that could be earned by either or both sides of the dyad, or discussing the possibility that either side of the pair would (or would not) compromise by taking a less favored time slot, this sentence was categorized into the *negotiation* category. Coders went

through the training session, during which they were given feedback to ensure similar understanding of coding scheme (inter-coder agreement was above 95% for all pairs of coders). Each coder coded a quarter of the conversations independently. Number of sentences involving negotiation was counted within each week.

Results

Performance

The *overall performance* did not differ among the three CMC groups (M = 13.58, 13.80 and 13.91, SD = .85, .41 and .49 for text, audio and video conditions, respectively, $F_{(2,47)}$=1.30, p>.05). To further understand whether a well balanced solution was reached as a result of negotiation, the *difference score* between each dyad was used as the dependent variable in the following analyses.

Level of Difficulty. Mixed-design analysis of variance (ANOVA) with *difficulty* as a repeated measure and CMC methods as between-subject variable yielded a significant interactive effect ($F_{(2,47)}$ = 4.78, p < .05) on the difference scores of dyads, suggesting that different CMC groups performed differently on easy vs. hard weeks. As illustrated in Figure 2a, the difference in participants' performances was comparable among three CMC groups for *easy* weeks ($F_{(2,47)}$ =1.20, p > .05). In contrast, difference in participants' performances on *hard* weeks differed for the three CMC groups ($F_{(2,47)}$ = 3.60, p < .05). Fisher's least significant difference (LSD) post-hoc comparison suggested that the difference in performance was higher for text and audio groups than video groups (ps < .05).

The results suggested that different CMC groups probably were engaged differently at different stages during the problem solving process. Text and audio groups probably were still placing most effort in collaboratively finding the solution space. As a result, they were less likely to move to the next stage of resolving conflicts if there was any. In contrast, participants in the video condition were able to reach a decision that better balanced the two sides' task performance, as reflected in a smaller difference score, suggesting that they probably were able to move into the conflict resolution stage on hard weeks.

Level of Conflict. Also taking participants' difference in performance as dependent variable, mixed-design ANOVA with *level of conflict* as a repeated measure and CMC methods as between-subject variable yielded a significant 2-way interactive effect ($F_{(2,47)}$ = 5.92, p < .01), suggesting that different CMC groups also performed differently on weeks with low vs. high levels of potential conflict.

As shown in Figure 2b, for *low-conflict* weeks, CMC methods had a marginal effect on dyads' difference in performance ($F_{(2,47)}$ = 2.42, p = .10). The effect of CMC methods was significant for *high conflict* weeks ($F_{(2,47)}$ = 4.40, p < .05). Fisher's LSD post-hoc comparison suggested that the difference in performance was lowest for the video condition, which was lower than text condition (p < .01), and marginally lower than audio condition (p < .10).

We can clearly see from Figure 2b that, as the bandwidth of CMC methods went higher from text to audio and from audio to video chatting, the difference score between dyads became smaller and smaller, probably due to the fact that they were more and more likely to get engaged in negotiation and conflict resolutions when they need to. To further unpack the impact of CMC methods, we examined the participants' time allocation on different week types and their patterns of exploration in the problem space.

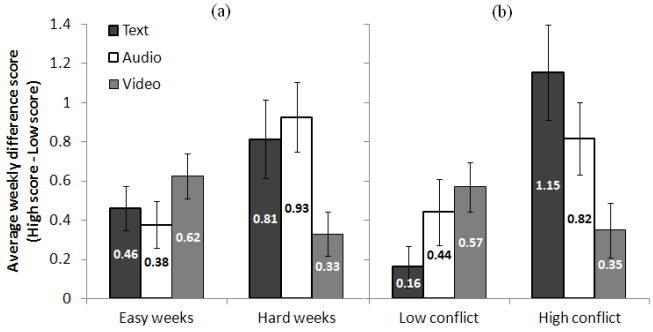

Figure 2. Difference score for easy vs. hard weeks (a) and for low- vs. high-conflict weeks (b) in text, audio and video groups

Task Completion Time

Level of Difficulty. Mixed-design ANOVA yielded a marginally significant 2-way interactive effect between *difficulty* and CMC methods ($F_{(2,47)}$ = 2.87, p = .07) and significant main effects of difficulty ($F_{(1,47)}$ = 14.31, p <.001) and CMC methods ($F_{(2,47)}$ = 36.16, p <.001). As we can see in Figure 3a, not surprisingly, participants spent more time scheduling hard than easy weeks, and text condition was more time consuming than audio and video conditions (Fisher's LSD, ps < .001). We were interested in whether participants using different CMC methods allocated time differently for easy vs. hard weeks. Further comparisons with paired-sample t-tests showed that participants in text ($t_{(16)}$=2.77, p<.05) and audio conditions ($t_{(15)}$=3.17, p<.01) spent more time on hard weeks than on easy weeks. Participants in the video condition spent similar amount of time on easy vs. hard weeks ($t_{(16)}$=1.45, p>.05).

Level of Conflict. According to mix-design ANOVA, the interactive effect between *conflict level* and CMC methods was not significant ($F_{(2,47)}$=.63, p>.05). The main effects of conflict level ($F_{(1,47)}$ = 5.30, p <.05) and CMC methods ($F_{(2,47)}$ = 32.83, p <.001) were significant. A similar pattern can be observed in Figure 3b that participants spent more time on high- than low-conflict weeks and texting was more time consuming than audio and video chatting (Fisher's LSD, ps <.001). We also conducted further analysis with paired-sample t-tests and found that time difference between high- and low-conflict weeks did not reach significance for text ($t_{(16)}$=1.32, p > .05) or audio ($t_{(15)}$ = .91, p > .05) groups. Participants in video condition spent more time discussing high-conflict weeks than the low-conflict ones ($t_{(16)}$ = 3.49, p<.01). However, interpretation of these t-test results should use caution due to the non-significant interaction between conflict level and CMC methods.

The results suggested that participants in different CMC conditions probably allocated time differently depending on task difficulty and level of conflict. Participants using text and audio chatting had a tendency of spending more time when it was harder to find solution candidates, whereas participants in video condition were more likely to spend more time when more conflicts need to be resolved.

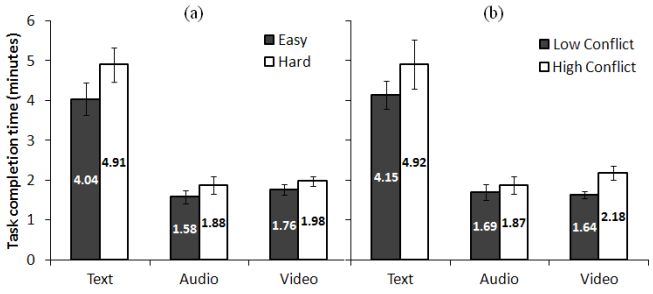

Figure 3. Task completion time for easy vs. hard weeks (a) and for low- vs. high-conflict weeks (b) in text, audio and video groups

Problem Space

To further understand the problem solving process that result in the performance and task completion time patterns discovered above, we examined the size of the problem space participants visited. We also paid special attention to the problem space they revisited, which indicated evaluation of solution options and negotiation.

Visited Problem Space. We compared the problem space visited by each pair for different week types. Mixed-design ANOVA with *difficulty* as a repeated measure and CMC methods as a between-subject variable yielded a marginally significant two-way interactive effect on the size of visited problem space ($F_{(2,47)}$ = 2.92, p=.06, see Figure 4a). Further comparison with paired-sample t-tests indicated participants visited a larger problem space on hard weeks than easy weeks in text ($t_{(16)}$ = 2.75, p<.05) and audio ($t_{(15)}$ = 4.31, p<.001) conditions, but not in video condition ($t_{(16)}$ = .51, p>.05). *Conflict level* and CMC methods had a marginally significant interactive effect on the size of visited problem space ($F_{(2,47)}$ = 3.09, p=.055, see Figure 4b). Paired-sample t-tests showed that only the video group had a tendency of exploring more of the problem space in high-conflict weeks compared to low-conflict ones ($t_{(16)}$ = 2.04, p=.06).

This pattern of the extent to which participants explored the problem space was consistent with their time allocation in the four week types. That is, when tasks became harder, participants in text and audio conditions visited a larger proportion of the problem space, which might result in longer time spent on hard weeks. In contrast, participants in video condition were more sensitive to the change in the level of potential conflict. When more negotiation was required for high-conflict weeks, they demonstrated a tendency of visiting more of the problem space and spending more time. This pattern of behavioral difference became even more evident when we analyzed the part of problem space participants visited for more than once.

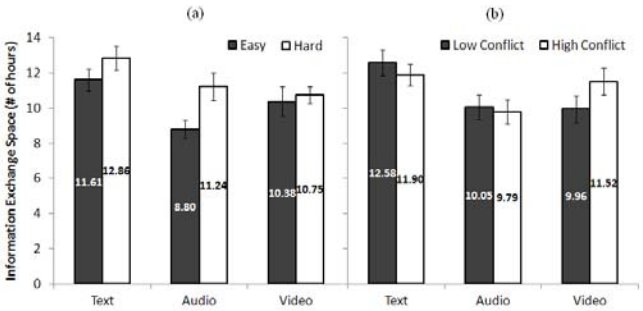

Figure 4. Number of hours mentioned per week for easy vs. hard weeks (a) and for weeks of different conflict levels (b).

Negotiation Space (Revisited Problem Space). Only a main effect of difficulty emerged from mixed-design ANOVA with *difficulty* as a repeated measure and CMC methods as a between-subject variable on the size of the negotiation space ($F_{(1,47)}$ = 6.23, p<.05, see Figure 5a). A significant 2-way interaction emerged between *conflict level* and CMC method when mixed-design ANOVA was used to analyze their effect on the size of the negotiation space ($F_{(2,47)}$ = 4.96, p<.05, see Figure 5b). Further comparison using paired-sample t-tests suggested that participants in video condition revisited significantly more hours in high-conflict weeks than in low conflict weeks ($t_{(16)}$=3.74, p<.01), probably as a result of more engagement in negotiation. In contrast, text and audio groups did not demonstrate such a behavioral pattern.

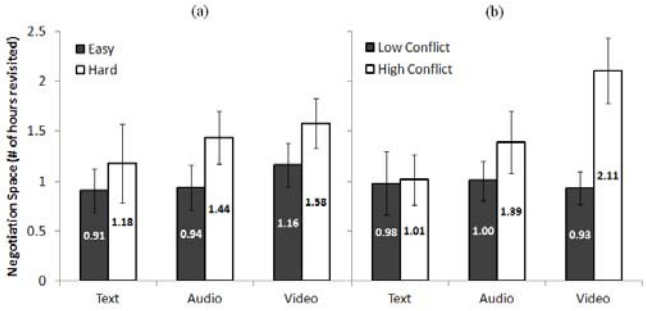

Figure 5. Number of hours revisited per week for easy vs. hard weeks (a) and for weeks of different conflict levels (b).

Negotiation

To control for the influence of overall talkativeness on participants' involvement in negotiation, we divided the number of sentences participants actually said (typed) on evaluation of points and negotiation for each week by the average number of sentences said per week by the CMC group this dyad was from and used this proportional score to represent participants' involvement in negotiation.

Mixed-design ANOVA did not find a significant interactive effect between *difficulty* and CMC methods on the extent to which participants involved in negotiation ($F_{(2,47)}$ = .35, p >.10, see Figure 6a). A main effect of week types ($F_{(1,47)}$ = 16.18, p<.01) suggested that hard weeks elicited more negotiations than easy weeks. The main effect of CMC methods was not significant ($F_{(2,47)}$ = 1.65, p >.10).

In contrast, *conflict level* and CMC methods had a significant two-way interactive effect on involvement in

negotiation ($F_{(2,47)}$ = 3.76, p < .05, see Figure 6b). Paired-sample t-tests comparing low- vs. high-conflict weeks suggested that the number of sentences devoted to negotiation was similar for text condition ($t_{(16)}$ = .03, p >.05), marginally different for audio condition ($t_{(15)}$ = 1.88, p =.08), and significantly different for video condition ($t_{(16)}$ = 5.21, p <.001). Thus, participants were more likely to negotiate and resolve conflict for weeks involving higher levels of potential conflict in video condition.

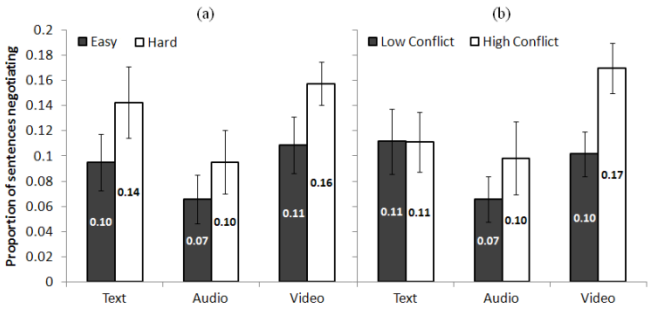

Figure 6. Involvement in negotiation for easy vs. hard weeks (a) and low- vs. high conflict weeks (b) in different CMC methods.

Discussion

In the current study, we examined the effect of text-based audio-based and video-based CMC methods on how people resolved conflicts and reached agreement in an appointment scheduling task. Two within-subject variables (difficulty, level of conflict) were introduced to further decompose the dynamics of interaction within participant pairs throughout the conflict resolution process. In particular, we focused on the difference in performance between each participant dyad because this difference was a good indicator of how well conflicts were resolved, and reflected the effectiveness of communication and negotiation in each CMC method.

In general, our results were supportive of the idea that higher bandwidth would help conflict resolution. First, participants who used the video-based communication method would more likely agree on solutions that were equally good to both parties, especially in difficult and high conflict weeks, than participants who used the text-based and audio-based methods. Second, task completion time and the proportion of visited problem space increased along with task difficulty for text and audio groups, but along with level of conflict for video group. Third, direct examination of the extent to which participant dyads engaged in negotiation also indicated that only participants in the video condition were more likely to be involved in negotiation by revisiting more of the problem space and by devoting more of the conversations to evaluation of different solution options and negotiation as a result of increased conflict level. Our further observation on the conversation dynamics suggested that participants using different CMC methods probably employed different strategies when exchanging time information and exploring the problem space, which in turn might have an impact on the outcomes of the following conflict resolution stage. Detailed analyses are needed on the conversation dynamics to further reveal the mechanisms of how different CMC methods were supportive of conflict resolution in tasks of similar type.

The results of the current study provided insights on how the dynamics of interpersonal interaction induced by different CMC methods could influence the negotiation and conflict resolution processes. We believe that one important metric for successful conflict resolution is whether both parties can agree on a solution that is equally good for them. A high difference in performance or earned benefits in remote conflict resolution tasks can bring long-term detrimental effects on how collaborators judge the overall value of the collaboration, as well as their mutual trust. In the long run, the trust and willingness to collaboration might diminish if either party perceives that there is imbalance of benefits or costs in the collaboration, which apparently would result in less efficient long-term effectiveness in the collaborative work. Therefore, special attention need to the paid to whether the interfaces of CMC tools could facilitate a feeling of "fairness" among remote collaborators when they need to resolve conflicts by remote communication.

The process of conflict resolution could become even more complicated when other factors (e.g., personality traits, cultural backgrounds and other features from the interface) are also taken into consideration in the dynamic process, or when different performance goals are introduced (e.g., individual vs. group oriented). This may imply that there is no single best CMC method for all remote collaborative works. Perhaps it is more reasonable to choose different methods depending on the nature of the remote task, the individuals performing the task, and the individual and/or collective goals of the team. Future research should be focused on the complex interactions of these factors during remote collaborative work.

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