Ambient Conversation Support in Small Face-to-Face Group Meetings

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ABSTRACT

Learner-centered learning methods have been considered for school education settings to help improve problem-solving skills of learners. Collaborative learning (CL), an approach in which two or more participants attempt to solve a problem together, has proven to be effective. Ambient support, which does not interrupt face-to-face interaction, is necessary in computer-supported collaborative learning or computer-supported cooperative work. Particular displays for such support are used in numerous recently released support systems. Much information, such as the number of utterances of learners and the degree of contribution to a discussion during the learning process, is represented on the displays by these systems; however, such support is not ambient because some participating learners watched the displays instead of focusing on other learners. In addition, support content for each learner is broadcast by these systems. According to research results, such broadcasting displeases some students; therefore, such support is not appropriate. In our research, we have aimed to develop an ambient conversation support system (ACSS) to solve these problems. First, we compared support methods of recently released systems (i.e., public conditions) with our developed approach (i.e., private conditions). Our experimental results indicate that (1) the average speech time per utterance under private conditions was statistically shorter than that of public conditions and (2) this average speech time per utterance under public conditions was statistically shorter than that of conditions in which participants were not supported by an ACSS (i.e., the no-support conditions). Experimental results and our discussion suggest that (1) the ACSS had a positive effect in support of increasing the number of participant utterances and (2) private conditions might pressure each participant against our expectations.

CCS Concepts

• **Human-centered computing**—Computer supported cooperative work • Human-centered computing—User interface design • *Hardware—Displays and imagers*

Keywords

Small-group Conversation; Face-to-face Conversation; Interaction and Conversation Support; Arduino

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1. INTRODUCTION

Numerous learning techniques have been made possible through collaborative learning (CL) and are observable via educational technologies. CL is a learning method conducted and applied in recent school education settings. In CL, learners make their decisions or produce their products by brainstorming, negotiation, and consensus building around a certain issue with one another [11]. In the Course of Study [16] for elementary schools performed from FY2011, regarding “periods for integrated study [16],” the Ministry of Education, Culture, Sports, Science and Technology in Japan (MEXT) suggests that teachers consider various learning forms, such as group learning and cross-age learning, as well as tutoring environments that include guidance from teachers with the cooperation of local residents.

MEXT also suggests that teachers lead students to solve problems with other students and write reports regarding their problem-solving procedures and research activities. Thus, MEXT has essentially reported the importance of group learning, i.e., CL that incorporates group learning is an important and recent topic in school education. Numerous studies focusing on CL and support of CL have been conducted. Recently, in [8], Hayashi et al. proposed a system that can visualize learner attitudes based on nonverbal information to the effective analysis of CL. In addition, in [7], Hayama et al. described technologies that can improve the quality of an argument by promoting the use of pre-learning knowledge in face-to-face CL.

Important viewpoints of CL include each learner’s process for making a decision and products, as well as the quality of interactions among learners. Knowledge and skills that each learner obtains are different due to the process, even if they can solve or discuss a problem. Therefore, developers of CL support systems should design an environment that can provide effective process support for each learner [16]. Learners face each other in general face-to-face CL; when a system supports such CL, rarefaction of the support is needed, i.e., the system needs to provide ambient support that does not prevent interactions [12].

On the other hand, in [19], Tomida et al. reported that effects that learners can obtain are different due to the number of learners participating in certain group meetings; in particular, when the number of learners is more than five, learners who do not communicate positively appear in the group meeting. In addition, in [17], Tada described that learners tend to split into subgroups in the middle of an argument when a large number of learners participate in a given group meeting.

In our current research, we focused on conversation support, which includes brainstorming, negotiation, and consensus building in small face-to-face group meetings. Systems that support conversation in small group CL or cooperative works (CW) have been proposed, including Conversation Clock [2],

Second Messenger [5], Meeting Mediator [13], and Social Mirror [3]. These systems were particularly effective in terms of conversation support; however, these systems used particular displays to support conversation and showed such information as the degree of each participant's contribution to a certain meeting, the number of utterances, etc. In such cases, there is the possibility that participants do not pay attention to other participants, instead focusing on the displays. Therefore, the support these systems provide is not ambient. In addition, information regarding a specific participant is broadcast by these systems (i.e., under public conditions); in [20], Yamada pointed out that a student tends to feel unpleasant knowing that other students know of his or her troubles in school.

From the aforementioned background, for ambient conversation support to provide an effective process for each learner, we conclude that recently released systems are not appropriate for conversation support in school education. In our research, therefore, we have tried to develop an ambient conversation support system (ACSS) for small group meetings. The target of the ACSS is cooperative works of participants including the learners who are not good at communication with others. By using the ACSS, we aim to increase number of utterances and facilitate turn-taking among the participants. An ACSS can support each learner's conversation and provide information only for a particular participant; therefore, we refer to this behavior as being under private conditions. For our purposes, we need to investigate the effectiveness under these conditions. In this paper, we aim to clarify the effectiveness here; concretely, we developed a prototype of an ACSS to measure the effectiveness and conducted an experiment to compare systems under the public and private conditions.

In addition to this introduction, the remainder of this paper is structured as follows. First, we present related work in Section 2. Next, we provide an outline of the ACSS in Section 3. A measurement experiment to compare the public and private conditions is explained in Section 4, with the results of this experiment provided in Section 5. We then discuss our results in Section 6 and provide conclusions and directions for future work in Section 7.

2. RELATED WORK

2.1 Communication Analysis in Conversation

In [15], Kumano et al. focused on nonverbal information, such as each participant's facial expression and gaze during conversations; they proposed an analysis method for conversation data that included such nonverbal information. In [4], Brennan investigated the difference of working efficiency depending on the sharing of participant conversation and gaze information in distributed cooperative works, reporting that there is a relationship between gaze sharing and work efficiency. In [8], Hayashi et al. proposed a system that can visualize learner attitudes based on nonverbal information toward the effective analysis of CL. They focused on learner gaze targets, speech intervals, and writing actions. Clearly, conversation data and nonverbal information are used to support CL.

As for communication analysis in CW, in [9], Hirai et al. analyzed communication between learners in pair-programming learning, reporting that success or failure of problem-solving was relevant to learner speech lengths or continuous speech in a problem-solving task with a time limit. In [10], Hu et al. also conducted a similar analysis, reporting that learner-pairs who can finish making their program smoothly tried to write program codes

immediately before and after their speech. These studies indicated the importance of conversation in CW.

In our current research, we focus on conversations in meetings. We also pay close attention to how a system provides conversation support for each participant in these meetings.

2.2 Conversation Support System

To date, numerous conversation support systems for CL and CW have been developed. In [7], Hayama et al. developed a face-to-face CL support system that successively provides materials used in participant pre-learning tasks. The system can estimate each participant's conversation status from conversation data dictated by using a speech recognition interface. In addition, the system can promote the use of appropriate materials according to the status and improve the quality of the argument.

In [2], Bergstrom et al. developed the Conversation Clock, which can show the degrees of each participant's contribution to a meeting by using the voice data of each participant. In [5], DiMicco et al. developed the Second Messenger, which can show similar degrees by using the number of participant utterances in a decision-making meeting; they reported that to show each participant's degree of participation to all participants affected each participant's contribution. In [13], Kim et al. pointed out that DiMicco et al. only focused on participant speech lengths and therefore developed the Meeting Mediator, which can visualize each participant's degree of interaction in real time. The Meeting Mediator estimates each participant's domination degree by using his or her speech information in a meeting; such estimation results are used to visualize each degree. In [3], Brandon et al. developed the Social Mirror based on the Conversation Clock noted above. The Social Mirror shows not only the degree of each participant's contribution but also the degree of his or her agreement with a certain issue, as well as the degree of interaction among all participants.

All environments introduced in this section had particular effectiveness in CL or CW; however, those systems show participant progress to all meeting attendees. Because of this, there is the possibility that such systems pressure participants and limit natural and smooth communication. In our current research, we focus on this problem and try to develop a conversation support system that can support each participant's conversation and provide information only to the particular participant.

2.3 Ambient Conversation Support

In [12], Kakusho et al. attempted to realize mediation and communication support via ambient systems, with the target being communication among teachers and learners in actual educational fields, including e-learning. In [18], Tanaka et al. attempted to develop a secretary agent that supports the beginning of smooth interactions between two humans or between a human and an information system. The agent can mediate user requests with an information system for certain tasks; however, these studies do not support conversation in small face-to-face group meetings.

3. AMBIENT CONVERSATION SUPPORT SYSTEM

First, we define the requirements of an ACSS. As mentioned in Section 2.2, recently released systems use particular displays to show such information as the degree of each participant's contribution to a meeting; however, when such displays are provided in a meeting, participants may not pay attention to other participants, instead focusing on the displays. From this problem

Figure 1. Circuit implementation for our ACSS.

and Yamada's findings in [20], as system's requirements, we defined 'participants do not stare at a conversation support system including such displays during meetings' and 'the system provides information including conversation support content only for the particular participant to be supported.' To develop a system that satisfies these requirements, we tried to implement an ACSS using light-emitting diodes (LEDs). In this chapter, therefore, we describe the implementation of an ACSS that uses an Arduino [1] that includes an LED lighting system.

3.1 Use of Arduino

Arduino is a digital input/output device that has an 8-bit microcomputer, six analog input pins, and fourteen digital input/output pins. In our research, we implemented an ACSS using Arduino-UNO.

The ACSS has three functions: a voice inputting function (VIF); a voice recognition function (VRF); and a support function (SF). Each participant uses one ACSS in a meeting. In VIF, a participant's voice data are sent to the VRF, which estimates the participant's conversation status and judges whether SF should support the participant or not. When VRF sends the judgment result to SF, if SF should support the participant, the LED turns on. In voice inputting, VIF needs to convert a participant's voice into a value to use as voice data on the Arduino. For this purpose, we used a condenser microphone. Further, we used an audio amplifier to improve the precision of voice inputs. We set up the microphone and amplifier on a breadboard and wired them together, as shown in Figure 1. Figure A shown in the Appendix section is the pseudocode embedded in the ACSS and Table A shows explanation of variables/functions using the pseudocode.

3.2 Preliminary Experiment

To determine the criterion to judge whether SF should support a participant or not, we conducted a preliminary experiment. Nine graduate students participated in this experiment. We divided these participants into three random groups consisting of three participants each and discussed a given theme for five minutes. The theme was to solve a riddle, which is a closed-ended problem. We recorded each group's conversation and analyzed it by using ELAN [6], which is an annotation tool for annotating video and voice data. In ELAN, we put marks as annotations on each participant's timeline with corresponding video data to measure the number of each participant's utterances and his or her speech time.

Two graduate students other than participants observed the annotated data and estimated the conversation status of each participant. As a result, they pointed out that (1) when all participants are quiet for more than five seconds, they cannot communicate smoothly and (2) when a participant is quiet for more than twenty seconds, they (i.e., the estimators) are uncomfortable. Based on these opinions, we decided to use "silence" as the criterion to judge the conversation status of each participant. In addition, we assumed that there are three statuses for each participant's conversation:

- Status 1: A participant is silent for more than twenty seconds
- Status 2: A participant is silent for more than five seconds
- Status 3: A participant is silent for five seconds or less

Figure 2. State transition diagram of LED in our ACSS.

Figure 3. Data collection settings.

We then determined that if the conversation status of a participant is Status 1 or 2, SF should support the participant. By using the status, the ACSS aims to increase number of utterances and facilitate turn-taking among the participants

Next, we attempted to determine the criterion to judge whether a participant talks or not. Concretely, VIF obtains voice data for each participant every fifty ms, and the VRF judges that the participant talks if the one-second average value, i.e., the voice data on the Arduino, is higher than a certain threshold. Because we found that this threshold is different depending on each participant's voice, we determined it before starting a meeting by obtaining and analyzing each participant's voice. Note that we conducted the determination process before starting the measurement experiment described in Section 4 below.

Thus, we implemented an ACSS that can recognize each participant's conversation status and turn the LED on accordingly. As for LED lighting, the estimators pointed out that the blue color was the most emphasized one among blue, red, and green. Therefore, we implemented the state transition shown in Figure 2, i.e., when the conversation status of a participant is Status 1 or Status 2, the LED illuminates blue or red, respectively. Moreover,

the aforementioned estimators discussed the LED lighting scheme. As a result, the estimators pointed out that they could easily identify who was silent and also identify their conversation status even if paying attention to other participants. From these opinions, we confirmed that the requirement of the ACSS, i.e., participants do not stare at a support system, was satisfied.

4. MEASUREMENT EXPERIMENT

To investigate the effectiveness of providing information only for a certain participant, we conducted a measurement experiment. The purpose of this experiment was to compare the public and private conditions noted above. Further, we investigated the no-support conditions in which the ACSS does not support each participant's conversation to confirm that the ACSS can support conversation.

4.1 Data Collection Procedure

Six undergraduate or graduate students who belonged to the same laboratory participated in the measurement experiment. We made six groups. Each group consisted of three participants. As for this grouping, there was certainly overlap, but there was never the same combination of participants in a single group. We presented an open-ended problem to each group and explained the ACSS. After that, participants of each group discussed the problem for seven minutes.

Figure 3 shows the settings for data collection. Participants of each group sat around a round table with a diameter of 0.8 meters. The distance each participant was from one another was 1.0 meter. We set the ACSS on the table such that each participant could see his or her own LED lighting even if he or she paid attention to other participants. Figure 4 shows screenshots under public conditions; the ACSS is in the circle shown in the figure. Under public conditions, each participant can see the other participants' LEDs. Conversely, under private conditions shown in Figure 5, he or she cannot do that. As for preparation of the private conditions, we confirmed that he or she could not see any other LEDs and could easily observe other participants' faces and gestures.

In the no-support conditions, all LEDs were guaranteed to not turn on although we set the ACSS LEDs on the table. We used two cameras to record each group's conversation. One camera was used to record the complete view, while another was used to record the behavior of all LEDs. Participants of each group discussed the given problems in the public, private, and no-support conditions, as shown in Table 1. Note that we considered counter balance to get rid of difference of experimental results based on conducting order of these conditions.

4.2 Data Processing

In our research here, we used the number of utterances, speech time, and rates of simultaneous speech to compare between the three aforementioned conditions. These criteria were used in many of the related works introduced in Section 2, as well as other studies focused on conversation analysis.

As explained in Section 3.2, we marked speech intervals of each participant and colors of each LED as annotations by using the recorded conversation data and ELAN. Regarding speech, we included nods and laughs. In addition, we used the Inter-Pausal Unit (IPU) [14] to check each participant's speech. IPU is a speech unit that is surrounded by pauses whose duration is longer than a certain time, which is approximately 100 ms to 300 ms. The time we used in our research was 100 ms. The total analysis time was 7,560 seconds (= 420 seconds × 6 groups × 3 conditions).

Figure 4. Screenshots under public conditions.

Figure 5. Screenshots under private conditions.

Table 1. Experimental procedure of each group

Group	First condition	Second condition	Third condition
1	No-support	Private	Public
2	Public	Private	No-support
3	No-support	Public	Private
4	Public	No-support	Private
5	Private	No-support	Public
6	Private	Public	No-support

Table 2. Number of utterances by each condition and group

Condition	Number of utterances of each group						Ave. (S.D.)
	1	2	3	4	5	6	
Public	158	111	133	134	115	123	129.0 (15.5)
Private	116	118	119	135	125	121	122.3 (6.3)
No-support	122	99	81	93	125	127	107.8 (17.7)

Table 3. Total speech time for each condition

Condition	Total number of utterances	Average speech time (S.D)	Maximum/minimum speech time
Public	774	4.51 s (6.45)	55.1 s/0.2
Private	734	4.25 s (4.30)	28.1 s/0.4
No-support	647	5.07 s (6.10)	40.7 s/0.3

Table 4. Rate of simultaneous speech for each condition

Condition	Rate of simultaneous speech
Public	80.4%
Private	69.3%
No-support	73.0%

5. EXPERIMENTAL RESULTS

In this chapter, we present results of our measurement experiments, including statistical discussion.

5.1 Accuracy of LED Lighting

First, we focus on the accuracy of the LED lighting. We investigated the accuracy by comparing each participant's speech length with annotations, as explained in Section 4.2 and the state transition diagram shown in Figure 2. We calculated the following formula for each group:

(The time length when LEDs turned on correctly)/(The length of discussion time (= 420 seconds))

As a result, accuracy ranged from 0.55 to 0.75. Further, a Kruskal-Wallis test revealed that there was no significant difference between the three conditions.

5.2 Number of Utterances

Table 2 shows the number of utterances for each condition and each group shown in Table 1. We observe here that the average number of no-support conditions was lower than that of other average numbers; however, a Kruskal-Wallis test revealed that there was no significant difference between the three conditions.

5.3 Speech Time

Table 3 shows the total speech time for each condition. As for the average speech time, a Kruskal-Wallis test revealed that there was a significant difference between the three conditions ($H = 10.37$, $p = 0.01$). In addition, the Steel-Dwass procedure revealed that a significant difference was noted between the public and private conditions ($p < 0.05$) and between the public and no-support conditions ($p < 0.05$). From these results and Table 4, we confirmed that the speech time per utterance under private conditions was statistically shorter than that of other conditions.

5.4 Rate of Simultaneous Speech

We defined simultaneous speech as the situation in which a participant speaks at the same time as another participant. According to this definition, we calculated rates of simultaneous speech for each condition by using the total numbers of utterances and simultaneous speech. Table 4 shows our calculation results. We observe here that the rate under private conditions is lower than that of other conditions; however, significant differences were not noted.

6. DISCUSSION

In this chapter, we discuss the results of our aforementioned measurement experiment.

6.1 Conversation Support via ACSS

We first discuss whether an ACSS can support each participant's conversation. From the results provided in Section 5.3, both the average speech time under public conditions and under private conditions were statistically shorter than that of the no-support condition. In this research, for conversation support, the LED turned on to inform a certain participant that he or she was silent. Therefore, the number of utterances under the public and private conditions may be increased. From these results, we proved that the ACSS had a positive effect on conversation support.

Conversely, there was a difference in the number of utterances and the rates of simultaneous speech among the three conditions, though their statistical significance was not proved. We conclude here that these results were caused by the different settings under the public, private, and no-support conditions.

Under private conditions, each participant cannot recognize the conversation status of other participants via their LEDs. Therefore, he or she might try to solve a problem (i.e., the color of his or her own LED is red or blue) as soon as possible. In other words, he or she might try to make his or her own LED turn off via longer speech patterns, because an LED turns off when he or she talks for more than one second.

6.2 Limitations of Our Research

As mentioned in Section 2, using nonverbal information in CL and CW may lead to better conversation support. In this research, we dealt with conversation as a fundamental criterion in the

analysis of CL and CW. Support and analysis that include such nonverbal information as turn-taking, participant's gaze, and facial expressions will be considered in our future work.

The ACSS supports conversation by using the conversation status of dozens of seconds and by controlling the decrease in silence. This support may not always be suitable. In fact, there are some people who speak after carefully thinking. This issue will also be considered in our future work.

As shown in Figure 2, the color of an LED becomes red or blue when a participant remains silent for more than five seconds or for more than twenty seconds, respectively. The color of the LEDs may impact experimental findings. We confirmed that the blue color was the most emphasized one among blue, red, and green according to opinions of the estimators (as mentioned in Section 3.2); however, the accuracy of LED lighting may affect our experimental findings. As noted in Section 5.1, the accuracy in our research here ranged from 0.55 to 0.75. Therefore, the ACSS may not support each participant's conversation correctly, even though there was no significant difference among the accuracy of the three conditions.

As noted in Section 3, the color of an LED depends on voice data using a microphone set on a breadboard of an Arduino-Uno. To avoid misrecognition of the microphone, we regulated the values obtained from the microphone by each participant, as mentioned in Section 3.2. Through our measurement experiment, we found that it is hard to recognize high-toned voices, whereas it is easy to recognize low-toned voices. To solve this problem, we deem it necessary to use a high-performance microphone and increase the number of amplifiers, another goal of our future work.

6.3 Toward Better Ambient Conversation

Support

As mentioned in Section 1, it is unpleasant for students when other students know of their troubles in school education settings [20]. According to this finding, we expected that it would be better for each participant in a meeting to find support from a conversation support system without airing such private information. From our experimental results, we revealed that such a setting may pressure each participant against our expectation.

In [17], Tada described that it is important for participants to listen to comments, opinions, and so on from other participants and react to them appropriately in a co-creative conversation whose purpose is to create something by communication, interaction, and negotiation. Tada also pointed out that silence has various messages, and human beings can communicate with one another by eye contact. These comments are relevant to the processes of CL and CW. In settings of our measurement experiment, it was possible to listen to other participant comments and react appropriately. In addition, we focused on each participant's silence as part of ACSS's conversation support.

Though there are many directions for future work, our research indicated the differences of conversation support under public, private, and no-support conditions in terms of each participant's speech and silence.

7. CONCLUSION

In this paper, we pointed out that (1) participants in CL or CW do not entirely pay attention to other participants but often focus on particular displays developed in previous studies and (2) participants find a CL or CW support system that shows

information such as each participant's degree of contribution in a meeting is problematic. We developed an ACSS to solve (1).

For solving (2), we tried to develop an ACSS that can provide information that includes conversation support content only for the participant to be supported. For this purpose, we needed to investigate the effectiveness of the presentation method. We therefore measured this effectiveness and showed experimental results by conducting a measurement experiment.

In the experiment, we compared the public, private, and no-support conditions by using an ACSS in terms of each participant's speech and silence. From these experimental results, we proved that the average speech time per utterance under public or private conditions was statistically shorter than that of the no-support conditions. From this, we conclude that the ACSS had an effect in increasing participant utterances. In addition, based on fact that there was a significant difference between the average speech time per utterance under public conditions versus that of private conditions, we concluded that the information display method under the private conditions may pressure each participant.

In addition to the directions for future work described throughout Section 6 above, our future work is essentially to consider support and analysis that includes nonverbal information in investigating the effectiveness of the ACSS. Refinements of the ACSS and further large-scale experiments are also part of our future work.

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Appendix

```

void setup(){ <Setting of a LED> }
void loop(){
  <Declaration of variables>

  for(;;){
    /* Detection of the first voice */
    level=analogRead(SOUND_SENSOR0);
    Serial.println(level);

    /* 1SEC = 50ms -> 20SEC = 1sec */
    if(SEC >= 20){
      if(heni > 400){ /* Talk */
        Loop3++; Loop1=0; SEC=0; heni=0;
      }else{ /* Silence */
        Loop1++; Loop3=0; SEC=0; heni=0;
      }
    }
    if(SEC < 20){
      heni = heni + abs(level - 525); SEC++;
    }

    /* Loop1 >= 5 -> 5sec silence */
    if(Loop1 >= 5){
      for(;;){
        /* LED Color -> RED */
        analogWrite(R_LED,0);
        analogWrite(B_LED,255);
        analogWrite(G_LED,255);
        < Detection of next voice >

        /* Loop2 >= 15 -> 20sec silence */
        if(Loop2 >= 15){
          for(;;){
            < LED Color -> BLUE >
            < Detection of next voice >
            delay(50);
          }
        }
        if(Loop1 == 0) break;
      }
    }
    /* LED -> Turn Off */
    analogWrite(R_LED,255);
    analogWrite(B_LED,255);
    analogWrite(G_LED,255);
    delay(50);
  }
  delay(50);
}

```

Figure A. Pseudocode embedded in the ACSS.

Table A. Explanation of variables and functions using in the pseudocode

Variables and Functions	Explanation
delay (time [ms])	Waiting time of the process
Loop1	Variable for detection of 5ms silence.
Loop2	Variable for detection of 20ms silence
level	Value obtained by the voice inputting function (VIF)
SEC	Variable for recording of elapsed time
heni	Variable for the voice recognition function (VRF)
analogWrite (LED's name, value)	Function for LED Lighting