Face-to-Face Holographic Agent Used as Catalyst for Learning and Employing Co-regulation in Collaborative Discussion

Toshio Mochizuki, Senshu University, tmochi@mochi-lab.net
Natsumi Yuki, Senshu University, y-natsumi@mochi-lab.net
Nariaki Ishikawa, The University of Electro-communications, ishikawa-egilab@inf.uec.ac.jp
Hironiri Egi, The University of Electro-communications, hiro.egi@inf.uec.ac.jp
Ayane Hisatomi, Okayama Prefectural University, hisatomi@hint.cse.oka-pu.ac.jp
Yutaka Ishii, Okayama Prefectural University, ishii@cse.oka-pu.ac.jp
Yoshihiko Kubota, Tamagawa University, kubota@kubota-lab.net
Hiroshi Kato, The Open University of Japan, hiroshi@kato.com

Abstract: This paper describes a preliminary study of a conversational holographic agent to help learners assess and manage their participation for encouraging co-regulation in face-to-face discussions. The agent works with a voice aggregation system which calculates each participant's ratio of utterances, each group's silence ratio, and turn-taking during the discussion in real-time, then produces prompting utterances with non-verbal actions to encourage learner participation, summarization, and clarification of what is said. The analysis showed that the agent's facilitation, which was based on the voice data, balanced the students' participation in collaborative discussions and allowed them to model how to regulate further discussions.

Introduction

Co-regulation is one of the various critical issues appearing in collaborative learning. An approach for tackling this issue is providing prompts or scripts from software or an agent to regulate the members' activity (e.g. Borge et al., 2018). Conversational agents are usually used in computer-mediated discussions. Related studies show a range of their effects that support collaborative learning (e.g. Dyke et al., 2013).

Robot facilitation (Miyake & Okita, 2012) is another promising type of conversational pedagogical agents for regulating face-to-face collaborative learning. Mochizuki et al. (2013) revealed that robot facilitation had more potential to create higher member-centered proactive participation than human facilitation did. However, facilitation robot agents are still in a research and development stage, and therefore currently expensive for mass introduction and actual effective usage in a classroom environment.

To tackle the issues mentioned above, we propose a three-dimensional holographic embodied conversational agent for face-to-face discussions. The agent works with a discussion voice aggregation system (Ishikawa et al., 2019) which collects all voice data of each member and calculates the following features of the interaction during the discussion: (a) each student's cumulative ratio of utterances (i.e. how long each student utters within every 20 seconds) and a group's ratio of silence durations for every 20 seconds; (b) each student's cumulative utterances frequency; (c) their cumulative turn-taking frequency and directions; (d) coefficients of speech overlap (in the case when the sum of (a) is more than 100%). The agent provides suitable prompts with non-verbal motions (nodding, pointing, turning its face sideways, etc.) based on real-time calculations. The prompting behaviors are designed based on the active listening strategies (Cormier & Cormier, 1998) adopted as a co-regulation strategy for collaborative discussion. When the agent prompts co-regulation in discussions based on the participation data, all participants are also expected to be able to monitor the balance of their participation without sharing explicit evaluations of each member's participation. This study aims to examine the effectiveness of the agent which we designed for promoting co-regulation of the students' discussion.

Methods

Thirty-six undergraduate students (Female 25.0%) were randomly assigned to two different conditions. They were asked to discuss three topics spending 12 minutes on each topic – "what *dream* means to you?", "what *happiness* means to you?", and "what *being an adult* means to you?". These topics were taken from junior high school textbooks and designed for students practicing collaborative discussions.

At first, the students in one condition were randomly assigned to groups of three, forming 6 triads, each triad worked with the agent that facilitated the discussion. The students in the other condition were assigned to groups of four, forming 4 groups without the agent, while one of the students in each group was randomly assigned as a moderator and instructed to manage the discussion using the same strategy as the agent did. After discussing the first two topics, the students were asked to switch the conditions and were slightly arranged in order for the different number of members required in each condition to be achieved, thus forming 6 triads with the agent and 5 groups of four without the agent. Then they discussed the third topic in a similar manner to the prior discussions.

The second and third topics were the target tasks for our preliminary analysis. We combined the data of each second and third discussions in order to counterbalance the conditions in each subsequent group the students join by swapping some students between groups and changing others' roles. Some of the discussions could not be analyzed due to lack of clear voice recording by the system. Thus, we analyzed 8 discussions with the agent and 7 discussions without the agent, respectively. In order to examine the effectiveness of the agent, we analyzed the time series data of students' participation; the data comprising each student's cumulative ratio of utterances and each group's cumulative ratio of silence durations, both data were generated every 10 seconds by the discussion voice aggregation system. Furthermore, in order to examine how the participation balance of each group varied during the discussions, we computed each group's Shannon entropy of cumulative ratios of utterances every 10 seconds. These analyses did not use the moderators' data because the moderators' amount of utterances was expected to be low. We also qualitatively examined the transcripts of each agent-less group's discussion in order to clarify how much the moderator students used the co-regulation strategy according to the instructions.

Results and discussion

Means values of the students' participation data and silence ratios in the two conditions (i.e., with or without a holographic agent) were calculated based on the time series data generated every 10 seconds by the voice aggregation system. Wilcoxon's signed rank tests did not show any significant differences of the cumulative ratio of utterances ($Z = -1.183$, $p = .237$) between the groups with an agent ($M = 26.99$, $SD = 10.95$) and those without one ($M = 22.34$, $SD = 10.22$), while the average of each group's cumulative ratio of silence in the groups with an agent ($M = 41.00$, $SD = 26.16$) was slightly lower than that in the groups without one ($M = 52.65$, $SD = 22.08$) which showed medium effect size ($Z = -1.690$, $p = .091$, $r = -.436$). Thus, the groups with the agents tended to elicit more stable (or continuous) discussions.

After we computed each group's entropy value based on each student's cumulative ratio of utterances, we examined differences of the participation balance between the conditions, revealing that students in the groups with an agent were more likely to contribute to the discussions ($M = .842$, $SD = .165$) than those in the groups without one ($M = .670$, $SD = .152$) which showed medium effect size ($Z = -1.859$, $p = .063$, $r = -.480$).

The qualitative analysis revealed that only one student moderator in the three groups used the strategy twice to regulate the discussions even though they were taught in advance to use it and they had practiced it in the first discussion, while after experiencing discussions with the agent all moderators in the four groups used several prompting messages several times ($M = 3.00$, $SD = 1.83$).

Thus, the agent could elicit continuous discussions and balance the students' participation based on real-time calculations of the cumulative ratio of utterances and silence durations. The prompts provided by the agent were powerful tools for the students to learn how to use the co-regulation strategy for collaborative discussion by modeling the agent. Simply providing instructions of the strategy by us and training the students on how to employ it were not enough for them to learn that, and therefore it was difficult for them to apply it. Presenting an agent as a model for co-regulation is a promising method which can accomplish dynamic learning of the co-regulation strategy. Further research is needed to pursue reasons why feedback from a holographic agent is more effective.

References

Borge, M., Ong, Y.S. & Rosé, C.P. (2018). Learning to monitor and regulate collective thinking processes. *International Journal of Computer-Supported Collaborative Learning*, 13, 61–92.

Cormier, L. S., & Cormier, W. H. (1998). *Interviewing strategies for helpers: Fundamental skills and cognitive behavioral interventions* (4th ed.), Pacific Grove, CA: Brooks/Cole

Dyke, G., Adamson, A., Howley, I., & Rosé, C.P. (2013). Enhancing scientific reasoning and discussion with conversational agents. *IEEE Transactions on Learning Technologies*, 6(3), 240–247.

Ishikawa, N., Okazawa, T., & Egi, H. (2019). DiAna-AD: Dialog Analysis for Adjusting Duration during Face-to-face Collaborative Discussion. *Proceedings of the 25th International Conference on Collaboration Technologies and Social Computing (CollabTech2019)*, LNCS11677, 212–221.

Miyake, N., & Okita, S.Y. (2012). Robot facilitation as dynamic support for collaborative learning. In J. Aalst, K. Thompson, M.J. Jacobson, & P. Reimann (Eds.) *Proceedings of the 10th International Conference of the Learning Sciences, Vol. 2* (pp.57–63). Sydney: International Society of the Learning Sciences.

Mochizuki, T., Mitate, Y., Tateno, Y., Wakimoto, T., Miyata, Y., Nakahara, J., & Miyake, N. (2013). Robot as a Learning Partner for Promoting Proactive Discussion in Peer Groups: A Case Study for Career Development. In L.-H. Wong, et al. (Eds.), *Proceedings of the 21st International Conference on Computers in Education* (pp.185–193). Indonesia: Asia-Pacific Society for Computers in Education.