Hayashi, Y., et al. (Eds.) (2017). Workshop Proceedings of the 25th International Conference on Computers in Education. New Zealand: Asia-Pacific Society for Computers in Education

An Experimental Investigation on Using Pedagogical Conversational Agents: Effects of Posing Facilitation Prompts in Oral-Based Peer Learning

Yugo HAYASHI

Ritsumeikan University, 2-150 Iwakura-cho, Ibaraki, Osaka, 567-8570, Japan

y-hayashi@acm.org

Abstract: This study investigates the use of pedagogical conversational agents (PCAs) that intervene in learner-learner collaborative learning activities. In addition, this study investigates how the quality of learning performance in a simple concept explanation task may change due to the use of multiple PCAs that pose different types of facilitation prompts to the learners. A controlled experiment was performed by comparing a condition using multiple PCAs wherein each PCA provided different types of facilitations with a condition using multiple PCAs wherein each PCA provided a mixture of the two types of facilitations. Using the WOZ method, this study reports the preliminary results of an analysis of oral-based peer learning. Lexical network analysis was used to understand the complexity of learner's semantic knowledge over two-time series. The results of the analysis show that when multiple PCAs were used with different facilitation prompts, the lexical network became more complex, showing that the learners developed a more sophisticated knowledge about the concept throughout their explanations. The significance of using multiple PCA is that it allows different types of contents to be considered during interaction.

Keywords: Pedagogical Conversational Agent, Explanation Activity, Collaborative Learning

1. Introduction

Learning through social interaction is known as one of the most effective strategies to develop deeper understanding (Vygotsky, 1980). Research shows that learning through sharing knowledge with others can lead to conceptual changes that can generate new knowledge (Chi, Leeuw, Chiu, & Lavancher, 1994). In addition, discussions based on different perspectives can bring an understanding of the content at higher levels of cognition (Schwartz, 1995). Studies on learning sciences have shown that explanation activity in peer learning can improve the quality of interaction and facilitate better learning performance (Miyake, 1986). However, such activities cannot be easily performed by novice learners and there is a need to investigate the type of interventions that can enhance their learning. This study focuses on the design of tutoring systems with conversational agents to facilitate peer to peer explanation activities. Additionally, it investigates the extent to which pedagogical conversational agents (PCAs) used in an explanation task are effective and examines how such techniques can improve learning performance. Further, this research particularly focuses on the use of multiple PCAs and investigates the most effective design of each PCA.

1.1. Using multiple pedagogical agents

Recently, studies on pedagogical technology have investigated the use of computer-based tutoring systems and PCAs in various types of tutoring settings (Moreno, 2005; Mayer, Johnsonb, Shaw, & Sandhu, 2006; Holmes, 2007; Graesser & McNamara, 2010; Louwerse, Graesser, Mcnamara, & Lu, 2008). Research on the development of such systems based on artificial intelligence has led to the development of systems using which learners can learn through teaching teachable agents (Biswas, Leelawong, Schwartz, & Vye, 2005; Matsuda et al., 2013). Previous research has also investigated the role of helping learners to compose explanations through the use of interactive tutoring systems (Graesser, Chipman, & Olney, 2005). However, most studies have focused on the nature of learner-PCA interaction, while very few studies focused on aiding learner-learner interaction. One of the advantages of human-human interactions is the high degree of success achieved in developing common knowledge through communication (Csibra & Gergely, 2011). Thus, considering this point, this study focuses on the use of PCAs in facilitating learner-learner interaction.

In this research, a series of studies has been conducted to investigate the effects of using a PCA in order to facilitate learner-learner collaborative learning. In Hayashi (2012), the author investigated the role of affective feedback from a PCA that provided prompts to facilitate the two learner interactions in an explanation task. Participants formed an explanation of a key concept, and the PCA intervened in the learner's activity and provided metacognitive suggestions, which were aimed at facilitating their explanation activities. In a further study(Hayashi, 2014), the effects of social influences, such as pressures from multiple PCAs, may produce more learner awareness toward PCAs and motivate learners to work harder on the task. It was also shown that compared to using only one PCA, the use of multiple PCAs can facilitate better explanation activities. However, although the effects of using multiple PCAs may raise learner's social awareness and facilitate their conversations, it was not clearly understood what type of facilitations/prompts from these PCAs are adequate for producing better quality of explanations. Furthermore, it is problematic to simply add the number of PCAs in such activities because the learner may not be able to consume all the information that is presented by the PCAs as they present several types of facilitations. Such situations may cause information overload (Jonston & Uhl, 1976), and it is predicted that learners may find it easier to absorb information when it is separately presented by different PCAs.

Studies on multimedia learning (Mayer et al., 2006) have examined the effect of cognitive load and suggested that learners understand the subject matter better when it is presented in the form of less multiple information sources by distributing such material via different communication channels. Therefore, considering this, this research investigated the use of facilitation prompts by distributing the contents of the facilitations between multiple PCAs, with each one playing different roles. Similar to Hayashi (2014), this study will set up a situation in which dyads will give explanations about a concept taught in class while receiving help from a PCA. Each PCA will present different types of learning material related facilitation prompts, which will enable them to clearly distinguish the types of facilitations and thus enable them to digest all the information that is posed to them and produce better explanations. The study focused on the use of two types of PCAs, which pose suggestions from different perspectives, such as the explanation adviser and the communication adviser. The study investigated whether the use of these PCAs would enable learners to produce better oral explanations and thus gain a more thorough understanding of the study materials.

1.2. Goal and Hypothesis

This study provides the preliminary results of an investigation into the use of multiple PCAs, which intervene in learner-learner explanation activities and provide facilitations related to the learning material. This study aims to investigate whether the use of multiple PCAs were each have different roles and provides different types of content-related suggestions. It was hypothesized that when the PCA intervenes in the learner's activities with multiple suggestions, learners may be unable to cognitively process all the comments from all the PCAs effectively. On the other hand, if multiple PCAs provide facilitations by individually taking on roles and splitting the learning content, learners may be able to process all the information and thus may generate explanations based on these different perspectives. From this viewpoint, this study conducts a controlled experiment by comparing two types of conditions: (1) a double condition wherein the two PCAs intervene by posing two mixed types of facilitation prompts (communication advice and explanation advice) and (2) a split double condition wherein two PCAs intervene by providing information to learners separately. One PCA will play the role of an explanation adviser and will pose suggestions related to topics on communication efficiency (i.e., how to ask effective questions to their partners). The other PCA will provide more cognitively related suggestions, such as asking them to try to think about the concept from various viewpoints and try to explain concepts from broader viewpoints. Thus, if learners consider these posed suggestions carefully, they should be able to develop their understanding of the subject by linking their existing knowledge with these more diverse approaches. Therefore, considering this point, one of the challenges of this study was to analyze learner performance using lexical network analysis in order to assess the quality of learner’s explanations (Hayashi, 2016).

2. Method

2.1. Procedure

The participants used two desktop computers and were asked to sit in designated places. A description of the key term was presented on the screen. Learners explained the key terms orally to each other while two PCAs appeared on the screen and provided suggestions. Learners in this experiment were required to formulate explanations of psychological terms such as ”short- and long- term memory” and ”figure-ground reversal.” The concepts were equally distributed among both conditions for internal validity. In the double condition, 12 worked on short- and long-term memory, and 14 worked on figure-ground reversal. In the split double condition, 12 worked on short- and long- term memory, and 12 worked on figure-ground reversal.

2.2. Experimental System

The experimental system was redeveloped based on the Java based platform created by (Hayashi & Inoue, 2015; Hayashi, 2014). It comprises two PCAs and enables feedback to be generated based on the learner’s utterances, which provided tips on how to form a sufficient explanation, applause, and back-channel feedback. The experimental settings were manipulated so as to match those used by (Hayashi, 2014) with one exception. In this experiment, the learners did not use text chat or wear headphones during the activity. Instead, they interacted orally. The experimenter manually inputted the keywords into the system using the WOZ method. Following the same rules as used by Hayashi (2014), when learners used words such as ”technical,” ”general,” ”trouble,” ”question pose,” and ”example,” they were inputted into the system. In addition, in the current experiment, the frequency at which PCAs provided messages were strictly controlled to ensure that all groups received the same number of facilitations from both PCAs. The experimenter inputted the detected keywords within a minute of utterance, and the learners in both conditions received a total of 10 messages each from the PCAs.

2.3. Participants and Conditions

The learners participated in this study as part of their coursework. One participant’s data were lost due to a technical issue. Each participant was randomly assigned to one of the two conditions, which varied according to the roles of the PCA suggestions (i.e., for double condition, n = 26, whereas for split-double condition, n = 24). In this experiment, the double condition was manipulated to ensure that both PCAs would provide suggestions; however, but their roles were not fixed as in (Hayashi, 2014), Either communicator advice or explanations were randomly generated. In the double condition, the PCAs responded randomly as either a communication adviser or an explanation adviser. No labels were visible to identify each PCA’s role nor were the instructions provided regarding the types of facilitations to be given.

In contrast, in the split-double condition, the types of facilitations used by PCAs were fixed and each was given a label describing their role affixed to the computer screen. In addition, to ensure that the learners could understand the PCA’s intentions clearly during the activity and to enable them to understand that they were working in a diverse group with divisions, they received explanations regarding each PCA’s role. In addition, participants in the split-double condition were provided with more specific information about their group. It was emphasized that their group was organized in a division of labor style. The merits of such group forms were also explained to the learners to ensure that they completely understood the nature of each agent’s role.

2.4. Dependent Variables

The main data were collected on two occasions as a free- recall test to explain about the key terms in a pre-test and post-test. The pre-test was conducted before the task, and the post-test was conducted after the task. These results are subject to lexical network analysis, as detailed in the following section.

3. Results

3.1. Lexical Network Analysis

3.1.1. Pre-processing

The first stage of analysis involves developing a dictionary database to collect a series of keywords that are used as the training dataset. While developing such a dataset, an expert (i.e., a teacher) was asked to create lists of words that could possibly relate to the instances of the key terms. As two intrinsically different types of concepts are used, a dictionary database is independently constructed and a network comprising 30 words is developed. For the pre-defined key terms for "long- and short-term memory," we used words such as "memory," "long," "short," "information," "temporary," "time," "necessary," "forever," "head," "save," "enormous," "amount," "embedded," "work," "storage," "brain," "always," "knowledge," "capacity," "process," "things," "behavior," "routine," "preserve," "moment," "period," "word," "constant," "playback," and "conscious." For the pre-defined key terms for "figure-ground reversal," we used words such as "ground," "meaning," "area," "picture," "background," "reverse," "link," "side," "person," "middle," "relation," "eye shot," "Rubin," "jar," "angle," "double," "apparition," "one way," "perspective," "attention," "conscious," "recognition," "aspect," "face," "human," "handle," "opposite," "things," and "diagram."

3.1.2. Network Analysis

Using the semantic dictionary database as the training dataset, the textual inputs from the learners were further analyzed. For each trial input, the number of appearances of the semantic keywords in the dictionary was counted and the data related to these semantic keywords were then analyzed using the aforementioned social-network analysis method. For each condition and phase, a network was developed based on a bipartite graph of keywords (i.e., 30 keywords *X* 18 participants). Each node represents the lexical category of the keyword that was frequently used in each participant's explanation. Fig. 1 and Fig. 2 show an example of the lexical network for participants in the split-double condition. The following equation represents the network density, where n denotes the number of nodes and l denotes the number of links:

$$\mathrm{d} = \frac{l}{n(n-1)} \tag{1}$$

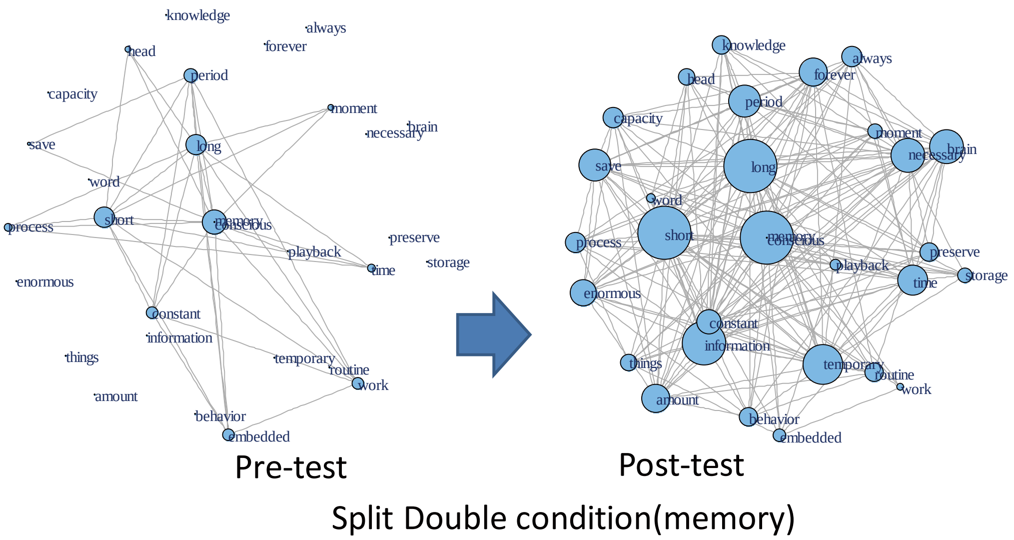

Figure 1. Lexical Network of the results in he split double condition (memory).

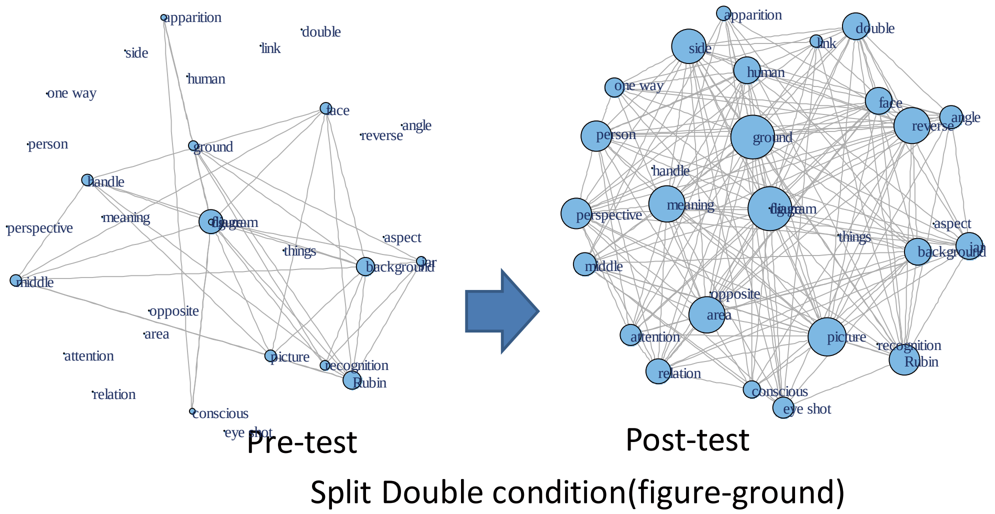

Figure 2. Lexical Network of the results in he split double condition(figure-ground).

Table 1, 2 summarize the results of the learners’ lexical density at each pre- and post-test. The results show higher lexical density in the split-double condition for the post-test of ”long- and short-term memory” (double = 0.28; split double= 0.459). From this result, we can conclude that learners used more sophisticated words in the post-test of the split-double condition compared to that of the double condition, depending on the type of predefined key term employed.

Table 1: Density results by condition and test: long-term and short-term memory.

	Pre-	Post-
Double	0.036	0.287
Split Double	0.085	0.459

Table 2: Density results by condition and test: figure ground reversal.

	Pre-	Post-
Double	0.002	0.457
Split Double	0.089	0.404

4. Discussion and Conclusions

This study aimed to investigate the use of multiple PCAs that each had different roles and provide different types of content-related suggestions. It was hypothesized that when a PCA intervenes in a learner's activities with multiple suggestions, learners may not be able to process all of their comments, while if PCAs pose facilitations by dividing the content, learners are more easily able to digest them and respond to their suggestions.

This study provides preliminary results from an analysis of learner's explanation performances using lexical analysis, which sheds light on how learners were able to develop more complex knowledge through the use of different types of learning support.

The results of the network analysis show that in both conditions, learners were able to explain the concepts in more detail in the post-test, where the network shows more complex links with learner's prior knowledge. This indicates that the learner-learner activity and the suggestions from the PCAs have improved learner's capacity to understand the learning material presented. In terms of the differences between the two conditions in the post-test, the use of multiple PCAs with different roles (split-double condition) shows a more complex network (0.459) compared to the pairs with no such distributed roles (double condition = 0.287) when explanations on the key term memory were given. However, there were no such differences between the distributed role condition (0.404) and no condition (0.457.) This suggests that there are advantages of using multiple PCAs with different roles due to the nature of the target concept they are explaining.

This study investigated the use of PCA interventions in learner-learner collaborative activities wherein students were communicating orally. In this experiment, the WOZ method was used to input the messages related to the learner's keywords into the system to provide feedback. However, in the future, it would be beneficial to develop a system that automatically detects the learner's utterances and provides customized feedback. Recent studies on ITS have investigated the method of detecting and providing facilitations based on learner’s modalities (D’mello & Graesser, 2013). Moreover, it is important to combine the implications from such studies in order to develop a more diverse structure of interactions between learners and several PCAs. In addition, it is necessary to conduct more analysis on how learners respond toward PCAs with different roles and further investigate what type of cognitive processes are at work when they received information from the distributed-role condition. Such further data analysis is presented in a different paper (Hayashi, n.d.) and a new experiment following the same conditions using learners’ text-based interactions are described here. This paper provides initial implications on how learners may respond to the suggestions from multiple PCAs during oral conversations using the WOZ method. The further study focus on the use of automated detection of the leaners textual input.

The author believes that the experimental setting shown in this paper can be generally applied to other contexts, such as in medical training as well as entertainment, which involves human-human interactions requiring help from systems. Therefore, the results of this study and the method used to analyze learner's knowledge may contribute to the design of future human-machine communication systems.

Acknowledgements

This work was supported by Grant-in-Aid for Scientific Research (KAKENHI), The Ministry of Education, Culture, Sports, Science, and Technology, Japan (MEXTGrant), Grant No. 16K00219.

References

Biswas, G., Leelawong, K., Schwartz, D., & Vye, N. (2005). Learning by teaching: A new agent paradigm for educa- tional software. Applied Artificial Intelligence, 19(3), 363- 392.

Chi, M., Leeuw, N., Chiu, M., & Lavancher, C. (1994). Eliciting self-explanations improves understanding. Cognitive Science, 18(3), 439-477.

Csibra, G., & Gergely, G. (2011). Natural pedagogy as evolutionary adaptation. Philosophical Transactions of the Royal Society B: Biological Sciences, 366(1567), 1149-1157.

D'mello, S., & Graesser, A. (2013, January). Autotutor and affective autotutor: Learning by talking with cognitively and emotionally intelligent computers that talk back. ACM Trans. Interact. Intell. Syst., 2(4), 23:1?23:39.

Graesser, A., Chipman, B., P. and Haynes, & Olney, A. (2005). Autotutor: An intelligent tutoring system with mixed-initiative dialogue. IEEE Transactions on Education, 48(4), 612-618.

Graesser, A., & McNamara, D. (2010). Self-regulated learning in learning environments with pedagogical agents that interact in natural language. Educational Psychologist, 45(4), 234-244.

Hayashi, Y. (n.d.). Facilitating collaborative explanation activities: Effects of splitting suggestion types using multiple pedagogical conversational agents. (submitted)

Hayashi, Y. (2012). On pedagogical effects of learner-support agents in collaborative interaction. In Proceeding of the 11th international conference on intelligent tutoring systems(its2012) (p. 22-32).

Hayashi, Y. (2014). Togetherness: Multiple pedagogical conversational agents as companions in collaborative learning. In Proceeding of the 11th international conference on intelligent tutoring systems(its2014) (p. 114-123).

Hayashi, Y. (2016). Lexical network analysis on an online explanation task: Effects of affect and embodiment of a pedagogical agent. IEICE Transactions on Information and Systems, E99.D(6), 1455-1461. doi: 10.1587/transinf.2015CBP0005

Hayashi, Y., & Inoue, T. (2015). Designing collaborative learning by multiple pedagogical conversational agents. IEICE transactions on Fundamentals A (Japanese Edition), J98-A(1), 76-84.

Holmes, J. (2007). Designing agents to support learning by explaining. Computers & Education, 48(4), 523-547.

Jonston, W. A., & Uhl, C. N. (1976). The contributions of encoding effort and variability to the spacing effect on free recall. Journal of Experimental Psychology: Human Learning and Memory, 2(2), 153-160.

Louwerse, M., Graesser, A., Mcnamara, D., & Lu, S. (2008). Embodied conversational agents as conversational partners. Applied Cognitive Psychology, 23, 1244-1255.

Matsuda, N., Yarzebinski, E., Keiser, V., Raizada, R., Stylianides, G. J., & Koedinger, K. R. (2013). Studying the effect of a competitive game show in a learning by teaching environment. International Journal of Artificial Intelligence in Education, 23(1), 1-21.

Mayer, R., E, Johnsonb, W., L, Shaw, E., & Sandhu, S. (2006). Constructing computer-based tutors that are so- cially sensitive: Politeness in educational software. Inter- national Journal of Human-Computer Studies, 1(1), 36-42. Miyake, N. (1986). Constructive interaction and the inter- active process of understanding. Cognitive Science, 10(2), 151-177.

Moreno, R. (2005). Multimedia learning with animated pedagogical agents. In R. Mayer (Ed.), The cambridge hand- book of multimedia learning (p. 507-524). Cambridge University Press.

Schwartz, L. D. (1995). The emergence of abstract representation in dyad problem solving. Journal of the Learning Science, 4, 321-354.

Vygotsky, L. S. (1980). The development of higher psychological processes. Harverd University Press.