On Pedagogical Effects of Learner-Support Agents in Collaborative Interaction

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Abstract. The present study was conducted to investigate if and how conversational agent can facilitate explanation activity that is conducive to learning. This was investigated through two experiments where pairs of participants, who were enrolled in a psychology course, engaged in a task of explaining to their partners the meanings of concepts of technical terms taught in the course. During the task, they interacted with a conversational agent, which was programmed to provide back-channel feedbacks and meta cognitive suggestions to encourage and facilitate conversational interaction between the participants. The findings of the experiments suggested that (1) a conversational agent can facilitate a deeper understanding of conceptwhen participants are attentive to its presence, and (2) affective positive feedbacks from conversational agent facilitates explanation and learning performance.

Keywords: collaboration, explanation activities, pedagogical agents, affective learning.

1 Introduction

Advances in communication technologies made it possible to develop a system which aids human interaction and supports cognitive operation. One of such enterprises includes researches to develop embodied conversational agents to support educational system. In the fields of cognitive science and learning science, researchers on collaborative learning have shown that successful understanding or acquisition of new concepts depends greatly on how explanations are provided. In this study the task of explanation is experimentally investigated by using a conversational agent that serves as a teaching assistant. The purpose of the experiment is to find out if the presence of conversational agents facilitates learning and what kind of feedback from the agents is most conducive to successful learning performance.

2 Related Work and Relevant Questions

2.1 Collaborative Problem Solving

In cognitive science, several studies on collaborative problem solving revealed how concepts are understood or learned. For example, researchers have shown that asking

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reflective questions for clarification to conversational partners is an effective interactional strategy to gain a deeper understanding of a problem or a concept (e.g. [12, 3, 15, 13]. It has also been demonstrated that the use of strategic utterances such as asking for explanation or providing suggestions can stimulate reflective thinking and meta cognition involved in understanding a concept.

All these studies suggest that how well one can explain is the key to understanding and learning of a concept. Explanation may, however, be successful if people have difficulties in retrieving and associating relevant knowledge required for explanation activity. This has been reported to be the case especially among novice problem solvers [4, 10]. Also, it may not help learn a concept if people cannot communicate well each other as in when, for example, they use technical terms or phrases unknown to others [7].

One of the ways to help collaborative problem solvers is to introduce a third-person or a mentor who can facilitate the task by using prompts such as suggestions and back-channels. In actual pedagogical situation, however, it is often difficult for one teacher to monitor several groups of collaborators and to supervise their interaction during explanation. Recent studies by [8, 1] demonstrated that the use of conversational agents that act as educational companions or tutors can facilitate learning process. Yet, it has not been fully understood if and what kinds of support by such agents would be more helpful for collaborative problem solvers. In this article, the author will further investigate this question through the use of meta-cognitive suggestions, and affective expressions.

2.2 Pedagogical Conversational Agents as Learning Advisers

In the field of human computer interaction, researches have conducted a number of experimental studies which involve the use of pedagogical agents (e.g. [9, 5]). In the next section, the author will explain the factors that are important for pedagogical conversational agents as learning advisors.

The Effects of Monitoring and Presence of others. One of the important considerations in the study involving human performance is the effect of the "external factor" or the social influence from other people around. Studies in social psychology have suggested that work efficiency is improved when a person is being watched by someone, or, that the presence of an audience facilitates the performance of a task. This impact that an audience has on a task-performing participant is called the "audience effect". Another relevant concept on task efficiency, but from a slightly different perspective, is what is called "social facilitation theory". The theory claims that people tend to do better on a task when they are doing it in the presence of other people in a social situation; it implies that person factors can make people more aware of social evaluation. [16], who reviewed social facilitation studies concluded that the presence of others have positive motivational affects. [8] is one of the experimental studies which investigated the effects of a programmed agent. In this experiment, an agent, which played the role of an assistant, was brought in to help a participant who explained a concept. In the experiment, three different environments were set up for

the 'explaining activity'. They were: (1) two participants working with a text-based prompt, (2) two participants working with a visual image of pedagogical agent which produced a text-based prompt, (3) one participant working with a visual image of pedagogical agent which produced a text-based prompt (in this setup, participants did not have a human co-learner and directly interacted with the agent). The result showed that the participants in the last two conditions did better than the first where only textual prompts were presented. It also showed that the participants in the second condition did not engage in the explanation activity as much as those in the third. The first finding of [8] that the participants in the last two conditions, who worked with the agent, performed better may be attributed to the fact that their task of explanation was being watched or monitored by the agent.

These results suggest that participants would do better in the task of explanation if they are more conscious of the presence of the agents or if they are given an explicit direction to pay attention to the agent. This is our first research question investigated in Experiment 1 described below.

The Effects of Affective Feedback. Another point to be taken into consideration in studies of human performance is the "internal factor" or the affective factor, which is just as important as the "external factor" discussed above. They affect people's performance in either negative or positive ways and several studies reported that such factors are especially important in learning activities [1]. For example, [2] revealed that positive moods can increase memory performance. [11] also demonstrated that positive state of mind can improve text comprehension. Moods may affect the performance of human activities both verbally and non-verbally. In a study by [9], which examined how positive and negative comments from conversational agents affect learning performance, a pictorial image of an agent was programmed to project a textual message to the participant; in the positive condition, a visual avatar produced a short comment like "this task looks fun", while in the negative condition, it produced a short comment like "I don't feel like doing this, but we have to do it any-way". The results showed that the conversational agents that provided the participants with comments in a positive mood furnished them with a higher motivation of learning.

The studies discussed above suggest that the performance of explanation would also be enhanced if suggestions are given in positive mood either verbally or through visual feedbacks. This is our second research question investigated in Experiment 2 described below.

Research Goal and Hypothesis. The goal of this study is to experimentally investigate if and in what ways conversational agents can facilitate understanding and learning of concepts. The role of an agent was to assist the paired participants explain concepts to their partners during the collaborative peer-explanation activity. The hypotheses tested in this study were:

1. the presence of a conversational agent during collaborative learning through explanation task facilitates learners' understanding of a concept (Hypothesis 1 or H1)
2. the use of positive expressions provided by a conversational agent facilitates collaborative learners' understanding of concepts. (Hypothesis 2 or H2)

3 Method

3.1 Experimental Task and Procedure

The two experiments were conducted in a room where the computers were all connected by a local area network. In both experiments, the participants were given four technical terms printed on a sheet of paper. They were: 'schema', 'short-term / long-term memory', 'figure-ground reversal', and 'principle of linguistic relativity', which had been introduced in a psychology class. They were asked to describe the concepts of these words. After this pre-test, they logged in the computer and used the program installed in a USB flash drive (see the next section for detail). The pairs of participants were communicated through the chat program and one of the paired participants was instructed to explain to their partner the meanings of the words presented on their computer screen one by one. When two of the four concepts were explained to their partner, they switched the roles and the other partner explained the rest of the two words to his/her partner. All participants received the same prompts of suggestions from the agent on how explanations should be given and how questions should be asked about the concepts. After this intervention, they took the same test in the post-test. The descriptions of the concepts they provided in the post-test were compared with those of the pre-test to analyze if the participants gained a deeper understanding of the concepts after the collaborative activity. The whole process of the experiment took approximately 80 minutes.

3.2 Experimental System

In the experiments, a computer-mediated chat system was set up through computer terminals connected via a local network and the interactions of the participants during the activity were monitored. The system used in the experiments was programmed in Java (see Fig. 1). The system consists of three program modules of Server, Chat Clients, and Agent, all of which are simultaneously activated. The pedagogical agent used in this study is a simple rule-based production system typical of artificial intelligence (The agent system is developed by the author's previous study). It is capable of meaningfully responding to input sentences from users and consists of three main modules: Semantic Analyzer, Generator, and Motion Handler. Textual input of all conversational exchanges produced by paired participants is sent to the semantic analyzer of the conversation agent. The semantic analyzer then scans the text and detects keywords relevant to the concepts if they are being used in the explanation task (e.g. "I think that a ***schema*** is some kind of ***knowledge*** that is used based on one's own ***experience***." (detected key words are shown in bold italic). Next, the extracted keywords are sent to the working memory in the generator and processed by the rule base, where various types of rule-based statements such as 'if X then Y' are stored to generate prompt messages (if there are several candidates of matching statements for the input keywords, a simple conflict-resolution strategy is utilized). When the matching process is completed, prompt messages are selected and sent back to the working memory in the generator. The messages generated by the rule base are also sent to the

motion handler module to activate an embodied conversation agent, a computer-generated virtual character which can produce human-like behaviors such as blinking and head-shaking (See next sections for details).

Several types of output messages are presented by the agent depending on the content of input text from the participants (see Table 1 below for examples). Only short back channels are sent when there are several related key words in a text (Type1 output); Messages of encouragement are given when the agent detects some keywords related to the target concept (Type 2 output, Type 3 output, Type 4 output).

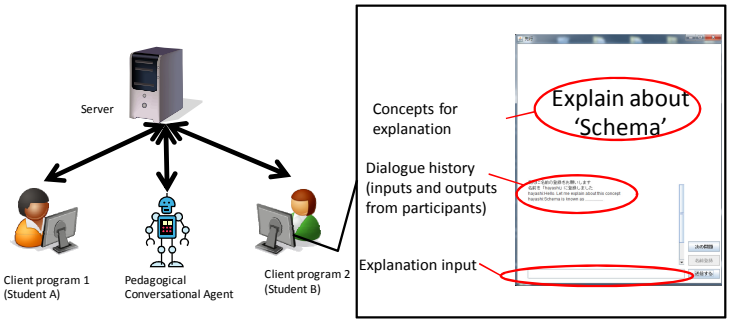

Fig. 1. Experimental environment and screenshot of the chat system

Table 1. Types of output messages from the agent

Type of output messages	Examples
Input messages (Detected key words are in Bold)	"I think that a **schema** is some kind of **knowledge** that is used based on one's own **experience**."
Type1output: back channels	"That's the way", "Keep going! ", "Um-hum"
Type 2 output: Suggestion	"You used few important keywords. Try to explain from a different perspective."
Type 3 output: Suggestion(positive)	"Wow! You used a few very good keywords. That's great! It is better if you explain it from a different perspective!"
Type 4 output: Suggestion(negative)	"Well, you used few keywords. That is not enough. It is not satisfactory unless you explain it from a different perspective."

3.3 Participants and Conditions

In this study, a total of 173 participants participated in two experiments (114 participants for Experiment 1 and 59 participants for Experiment 2). The participants were all undergraduate students who were taking a psychology course and participated in them as part of the course work. They were randomly assigned to three conditions, which varied with respect to how prompts of suggestions were presented and how

conversational agents were used (see the sections below for details). In conditions of odd numbers, a group by three participants was composed.

Experiment 1. The purpose of Experiment 1 was to test H1: the presence of a conversational agent during explanation task facilitates understanding of concepts. This was investigated through three conditions (See Fig. 2). In the first condition (Group SST, n = 37), participants were provided with (just) text-based prompts which provided them with suggestions to facilitate the explanation task. In the second condition (Group SSA, n = 38), the participants were provided with text-based prompts through a chat-dialogue setup and also with a picture of a conversational agent shown on the display. Also, the participants were told that the agent will play the role of mentor; this direction was included to make them more conscious of being monitored by the agent. The third condition (Group SSA+, n = 39) was the same as the second condition except that the virtual character was an embodied conversational agent which uses its hand gestures while the participants chat on the computer. The figure was manipulated by the 2D-image/avatar-design tool (http://avatarmaker.abistation.com/). The second and third conditions were used in order to find out the effects of pictorial presentation of an agent upon the explanation task. In both of these conditions, a pedagogical agent provided participants with back-channel feed-backs as they chat (see Table 1 for examples of backchannels).

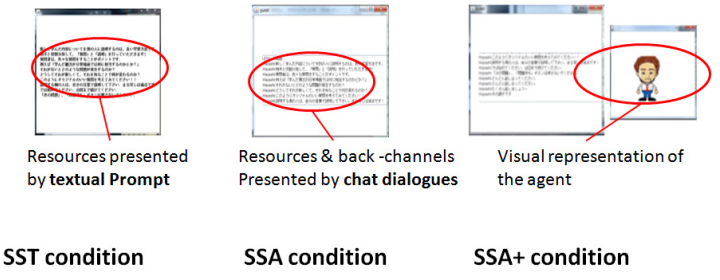

Fig. 2. Experimental conditions for Experiment 1

Experiment 2. Experiment 2 was conducted to test H2: the use of positive comments by conversational agent facilitates explanation activities and as a result, fosters understanding of concepts. To find out how affective factors influence the task of explanation, two types of avatars with more realistic appearance were created using a 3D-image/animation-design tool called Poser 8 (www.e-frontier.com): one is the "positive agent" with friendly facial expression and the other is the "negative agent" with unfriendly facial expression, which were used for the "positive condition" and the "negative condition" of the experiment, respectively. In the positive condition (Group SSA+P, n = 31), the participants were given positive suggestions, which were synchronized with the facial expressions of the positive agent. In the negative condition (Group SSA+N, n = 28), the participants were given negative suggestions, which were synchronized with the facial expressions of the negative agent (See Fig. 3). The messages were given through chat dialogue and the virtual character moved its hand

gestures while the participants chat on the computer (For examples of suggestion for the conversational agent see Table 1).

Fig. 3. Positive and negative facial expressions of the agent in Experiment 2

Dependant Variables. After Experiment 1 and Experiment 2, the participants who took the pre-test and post-test were asked to describe the concepts of the same technical words. The results of the pre- and post- tests were then compared to find out how the explanation task with different conditions facilitated their understanding or learning of the concepts. For the comparison, their descriptions were scored in the following way: 1 point for a wrong description or no description, 2 points for a nearly-correct description, 3 points for a fairly-correct description, 4 points for an excellent description, and 5 points for an excellent description with concrete examples. It was judged that the greater the difference in scores between the two tests the higher the degree of the effect of explanation.

4 Results

4.1 Experiment 1

The results of the Experiment 1 showed that the participants' understanding of the concepts (see Fig. 4 left). The vertical axis represents the average scores of the tests for the three groups at the times of pre- and post- tests. A statistical analysis was performed using a 2 x 3 mix factorial ANOVA with the two evaluation test-times (the pre-test vs. the post-test) and the three groups with different task conditions (SST vs. SSA vs. SSA+) as independent factors.

There was significant interaction between the two factors ($F(2,111) = 11.78$, $p < .01$). First, an analysis of the simple main effect was done on each level of the interface factor. In the SST, SSA, and SSA+ condition, the average scores in post-test was higher than pre-test respectively ($F(1,111) = 21.76$, $p < .01$; $F(1,111) = 119.59$, $p < .01$; $F(1,111) = 104.4$, $p < .01$). Next, an analysis of the simple main effect was done on each level of the period factor. In the pre-test, there no differences between conditions ($F(2,222) = 1.27$, $p = .28$). Although in the post-test there were differences between conditions ($F(2,222) = 20.27$, $p < .01$). Further analysis on the post-test was

conducted using the Ryan's method. Results indicate that the average score of SSA+ was higher than SST, and the average score of SSA was higher than SST respectively ($p < .01$; $p < .01$). There were no differences between SSA and SSA+ ($p = .35$). The overall results of Experiment 1 suggests that the collaborative activities facilitated the participants' understanding or learning of the concepts more when the presence of the third party, which gave suggestions for explanations, was made more explicit; in other words, the results show that H1 was supported.

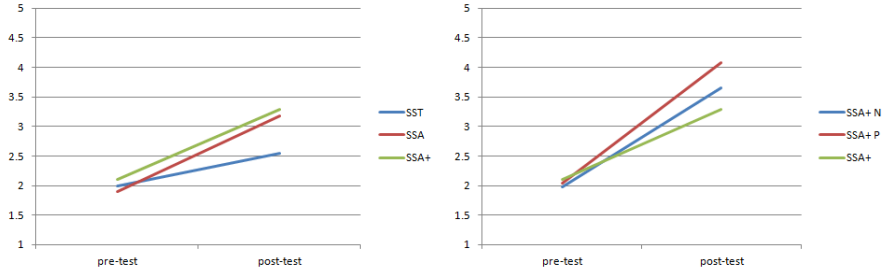

Fig. 4. Results of experiment 1(left) and experiment 2(right)

4.2 Experiment 2

The results of the Experiment 2 showed that the participants' understanding of the concepts (see Fig. 8 right). The vertical axis represents the average scores of the tests for the three groups at the times of pre- and post- tests. A statistical analysis was performed using a 2 x 3 mix factor ANOVA with the two evaluation test-times (the pre-test vs. the post-test) and the three groups with different affective conditions (SSA+N vs. SSA+P vs. SSA+) as independent factors. For the group with SSA+ condition, the same data used in Experiment 1 was used in Experiment 2.

There was significant interaction between the two factors ($F(2, 95) = 10.90$, $p < .01$). First, an analysis of the simple main effect was done on each level of the interface factor. In the SSA+N, SSA+P, and SSA+ condition, the average scores in post-test was higher than pre-test respectively ($F(1,95) = 172.86$, $p < .01$; $F(1,95) = 254.50$, $p < .01$; $F(1,95) = 87.85$, $p < .01$). Next, an analysis of the simple main effect was done on each level of the period factor. In the pre-test, there no differences between conditions ($F(2,190) = 0.48$, $p = .62$). Although in the post-test there were differences between conditions ($F(2,190) = 18.64$, $p < .01$). Further analysis on the post-test was conducted using the Ryan's method. Results indicate that the average score of SSA+P was higher than SSA+N and the average score of SSA+P was higher than SSA+, and the average score of SSA+N was higher than SSA+ respectively ($p < .01$; $p < .01$; $p < .01$). The overall results of Experiment 2 suggests that the collaborative activities facilitated the participants' understanding or learning of the concepts more when the positive suggestions were; in other words, the results show that H2 was supported.

5 Discussion

5.1 H1: Effects of the Presence of a Conversational Agent

The results of Experiment 1 suggested that the use of a conversational agent which provide relevant suggestions is more effective to facilitate explanation activities that result in a deeper understanding of concepts (i.e., Group SSA+ > Group SST, Group SSA> Group SST). The present experiment also provided some new evidence on the effectiveness of "audience effect", the effect of making people aware of the presence of a mentor, and the use of cognitive suggestions and back-channels, which was not investigated in similar studies in the past (e.g. [8]). One interesting finding in this experiment was that there was no difference between the group which was not provided with a visual representation of the agent (SSA+) and that which was provided with a visual representation (SSA). It may be that a mere mentioning of the instruction to the participants such as "the agent is your mentor and it's watching you", without showing the visual image of the agent, was sufficient enough to derive the " audience affect" [16]. On the contrary, it can also be predicted that the visual representation of the agent in the experiment did not have a discriminating effect upon the degree of attention as much it was expected to. This will be further discussed below.

5.2 H2: Effects of the Affective Expressions of the Conversational Agent

The results of Experiment 2 suggested that the greater the affective input from the conversational agent the more it can facilitate explanation activities which leads to a deeper understanding of concepts (i.e., Group SSA+P > Group SSA+N > Group SSA+). This experiment, examined the effects of affective expressions using both 'verbal message' and 'visual representation, which few others have looked into (e.g. [9]). As noted above, one very interesting finding was that Group SSA+N, to which suggestions and facial expressions of negative kind were given, scored higher than Group SSA+, to which suggestions and facial expressions of neutral kind were given, though not as high as Group SSA+P, to which suggestions and facial expressions of positive kind were given. This may suggest that the participants actually paid more attention and worked harder when they received negative comments than they received neutral comments. Some studies claim that negative comments presented through the media have a strong facilitation effects on memory [14]. The possibility that negative comments had a strong facilitating effect on this condition might be related to such effects. This point will be further investigated elsewhere.

6 Conclusion and Future Work

The present study investigated the effectiveness of the use of a conversational agent in a collaborative activity, where paired participants explained each other the meaning of technical terms taught in a psychology class for a better understanding. Conversational agents were used to encourage and facilitate the students' interaction through both

verbal and visual input. The experimental results suggested that the awareness of the presence of a conversational agent can trigger a deeper understanding of a concept during an explanation and that not only positive input but negative input from the conversational agent facilitate explanation activities and thus enhance learning performances. Pedagogical agent can play several different roles for collaborative learning activities and several studies have looked into the effectiveness of the use of a pedagogical agent with different roles. For example, [1] investigated the effectiveness of the use of a pedagogical agent which plays the roles of an expert teacher, a motivator, and a mentor (both an expert and motivator). However, not much is known yet about what roles it can play effectively. Another issue to be further investigated is the effect of the personality of the agent upon these roles. These and other related topics need to be further studied in future.

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