An investigation of the differences between robot and virtual learning companions’ influences on students’ engagement

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Abstract

We investigate the differences of the influences between robot and virtual learning companions on students’ engagement. From the analysis of our experimental result and interview, we found that virtual learning companion and robot learning companion both rose up students’ motivation and engagement. The differences between these two types of learning companions is that one of them made subjects more concentrated on the task and the other extended subjects’ time on task. We shall offer some advices for the researchers who design learning companion systems.

1. Introduction

In the last two decades, many kinds of learning companion have been adopted in several situations. In 1988, the concept of “learning companion” was first introduced by Chan and Baskin [1]. The main idea of learning companion was that computer plays the role of teacher and also provides a companion studying with students. Many researchers further found that learning companion could be integrated into different pedagogies. Troublemaker, for example, is a learning companion system which creates cognitive conflict to promote learning [2]. Hietala and Niemirepo also suggested that different levels of companions can increase students’ motivation to collaborate with learning companion [3]. Moreover these virtual characters can increase students’ motivation to sustain in a learning environment and more engaged in the learning activities [4]. Animated pedagogical agents can promote students’ motivation, engagement, and also engender affection as well as cognitive responses [5].

In the middle 1980s, Rodney Brooks proposed behavior-based robotics [6], where the intelligence of the robot could be determined by the dynamics of interaction between the subject and environment. In the field of education, most of robots are used in assembling robots with special modules to achieve the setting goal, to learn programing skills by coding, or to learn related knowledge through controlling robots. Robots provide an engaging environment usable for users with a variety of physical or cognitive challenges [7]. Learning companion system is not only in the cyberspace but also can be designed in physical world. In addition to virtual learning companion, robot with physical body is also adopted in the use of learning. Children nowadays live in the environment with high technologies and digital equipments. Games and toys are all more advanced than traditional ones. People find the power of toys and games, then use them in education. Adopting games, toys, and robots in education is a trend and this is just the beginning of next generation of digital learning.

One of the most important distinctions between virtual and real media is modality [8]. Real and virtual environments have not only psychological but also
physiological effects to people such as the influences of spatial memory and memory [9]. There are many advantages in virtual environment. Virtual environment provides people a cheaper, effective, and safe training place [3]. In the virtual environment we can simulate a lot of situations that real world can not be simulated. By the same token there is also much of advantage in physical environment. We can sense many things and get information via our sight, hearing, olfaction, palate and tactus. Virtual and real environments have different kinds of advantages. That is why many researchers try to bridge physical and virtual environments together [10].

A lot of research had found that virtual companions are helpful to students’ learning. In prior study, we find robot companion can have good interaction with children so long as children believe the robot is not controlled by others [11]. But there are still with inadequate evidences and strong motivations to prove the necessity of adopting robot companions into education. For these reasons, we try to compare the influences on students’ engagement which made by virtual companion and robot companion (a physical companion). In this paper we will observe and analyze data to understand the different of influences on students’ engagement when they are learning with their different learning companions.

2. Engagement

Words such as “concentrate”, “pay attention”, “engaged in”, in general mean that someone dedicates himself/herself to do something. Corno and Mandinach had defined the term of cognitive engagement and made a form of it which describes the level of cognitive engagement [12]. Thus engagement could be external actions, behaviors, or psychological expression during different situations. No matter which figure the cognitive engagement is, as long as people are giving sustained, engaged attention to a task requiring mental effort and cognitive engagement can be observed [13]. There is no direct evidence that engagement is the factor related to success, but we can find that engagement have to consistently been linked to reduced dropout rates, increased levels of student success, and with better personal learning and development [14], [15].

3. Experiment

There are 47 elementary students (22 males, 25 females) participating the experiment. These participants are all 4th grade. Before the experiment, a mathematic pretest was executed to the students.

3.1. Learning environment

Our goal is to investigate the difference between robot and virtual learning companions. A simple game with visual or robot companion for 4th-grade mathematic is implemented, called “Aibo in mathematic wonderland” (as shown in figure 1). The game story is as follows: One day you and your pet - Aibo lost in a strange place and it is time for dinner, you should go home as soon as possible. However the only way home is to solve the questions in mathematic wonderland. Could you solve the questions and go home with Aibo? There are seven stages in this game, and every stage covers different topics. For example, the third stage is on decimal question, and the sixth stage is on fraction. When players press the buttons to answer, the system will give feedbacks to players. Via the system’s feedback players will know whether their answers are correct or not. To avoid players to feel bored, we create different kinds of feedbacks in each stage and events. In order to keep learners playing the game, we also design some special feedbacks while players proceed in below three statuses: stage clear, game over, and game clear.

Figure 1. Screen shot and context descant of “Aibo in mathematic wonderland”

3.2. Robot companion

Toys are always children’s favorite and their companions. As time goes by, traditional toys are improved by motors, sensors, micro chips, embedded systems, and small energy supply system with high electric capacity. Although their appearances are still similar to traditional ones, but these new technologies make toys much smaller [16]. Until now, with the invention of wireless network and tiny processor, smart toys are transformed to another type – digital.
toys. With advanced technologies digital toys, like such students undoubtedly love to have company with.

Sony’s Aibo is a classic digital toy, animal appearance robot, with computing power inside and wireless communication ability. Besides above advantages Aibo is a programmable pet-type digital toy. By coding new software people can have new experience with Aibo. Aibo is a versatile digital toy. The usage of Aibo is not only fun with people but also can be adopted in education. Researchers transform Aibo into an educational robot. Recently Aibo is used in RoboCup (coding, artificial intelligence design), human robot interaction observation, and being educational appliances in classroom. A physical companion is chosen as Aibo in our experiment.

Sony has released development kit for Aibo, so that we use the development kit to create several Aibo actions for the game. To avoid situations that participants are confused by ambiguous actions, we have an inspection of these actions. Of the 37 elementary school students (16 male, 21 female), we randomly displayed 10 of Aibo actions, and asked them to recognize the meaning of the actions. All motions were validated by them and with high rate of recognition (98.3% of correct answer).

3.3. Method

In this pretest, 16 mathematic questions were chosen and the test time was 15 minutes. The domain of these questions is on 4th-grade of mathematics. The purpose of the pretest was to distinguish students’ abilities on mathematics. So that the three groups have similar performance on average

After pretest we asked participants to answer a questionnaire. According to the sample of National Survey of Student Engagement [17] we did some modification on these questionnaires. There are two parts in it: nine questions covered student profile and twelve investigated the engagement level in school and usual time. The purpose of this questionnaire was to understand each student’s profile, studying habits, and engagement level. And this questionnaire will be compared with another questionnaire about their engagement level in the game which participants were required to answer after the experiment.

There are three sets in the experiment. They are called control set (7 male, 8 female), experiment set A (7 male, 9 female), and experiment set B (8 male, 8 female). The variable of these three set is the media of learning companion. According to four forms of cognitive engagement level, we set the game as a task and investigate participants’ cognitive engagement on task focus. During they played the game we also recorded the process by video recorder and got data by computer. In order to measure their cognitive engagement we defined three factors of engagement in this experiment: consistency, concentration, and the confidence of engagement level [18].

Consistency is the total time that participants devote in the task and take their focus on the things about the task. In other words, consistency is the total time they spending in the game by subtracting the time of they strayed from the game and consumption of system feedback. We do not consider system feedbacks as “task focus”. It is the motivation which drives participants staying in the game longer. This is the reason why we do not count the feedback time.

Accuracy is another check item of consistency. There is a situation, a participant spends his time in the game, but he just moves the mouse and clicks. For sure, the accuracy is much lower than the result when participants take the game seriously. We had a mechanism to detect the possibility of this situation. If the accuracy is lower than 50% in the period of experiment, and we will treat this situation as distraction.

Concentration is the proportion of consistency. The higher proportion of consistency of result is in the experiment, the more engagement which participants devote in the task.

Confidence of engagement level is judged by two questionnaires. One is answered before the experiment, and the other is after the game. These two questionnaires provide us information of their impressions to the game and how different in their engagement level between school time and game.

3.3.1. Control set. The control set is a computer within the game. The screen was separate into two areas – the upper area was question panel and the bottom one was the answer panel (as shown in figure 2). When the game started, the upper area will display question for participants, and they answer the question by clicking the answer panel. After answering the question, the system will show the result of their answer in the upper area. When special periods occur (stage clear, game over, game clear), the screen will return to full screen mode. Special period will show in the full screen mode.
3.3.2. Experiment set A. Experiment set A is almost the same as control set. Except the arrangement of screen is not the same. There are three parts of the screen. First part (the left side of upper area) is question panel. Second part (the right side of upper area) is learning companion panel. The last part, answer panel, was in the bottom of the screen.

We prerecorded the actions of Aibo. The learning companion panel is the place displaying the video of Aibo’s actions. As long as participants answer a question the learning companion panel will display the video and the participant can realize that whether their answer are correct or not.

If the participant is concentrating on the screen, their focus will move as a loop from the question panel to answer panel then move to learning companion panel and back to question panel (as shown in figure 3).

3.3.3. Experiment set B. Experiment B is much different from the other two sets. In this set, there are two screens and Aibo. The architecture is the same as experiment set A, and the move of focus is similar to experiment set A. In the experiment set, the use of screen 1 is question panel, and screen 2 is answer panel (as shown in figure 4 and 5). System feedback will be presented by Aibo and screen 1. Screen 1 displays the context of the game and stage clear information. The role of Aibo is to respond the correctness of answer and react when special events are triggered.

In summary, in experiment set A we use video of Aibo as a virtual companion; in experiment set B, we use a physical one, the goal of this study was to observe the interaction of human and robot companion, and the influence of robot companion on students’ engagement. At last we compare the influences caused by experiment set A and B.

| Table 1. Screen arrangement of the experiment sets |
|----------------|------------------|---------------|
|                | Question Panel   | Answer Panel  | Learning Companion |
| Control Set    | Upper area       | Bottom area   | Without companion  |
| Experiment Set A | Upper left       | Bottom area   | Virtual (Video)   |
| Experiment Set B | Screen 1         | Screen 2      | Physical (Aibo)   |

Figure 2. The experiment environment of control set

Figure 3. The experiment environment and move of focus in experiment set A

Figure 4. The experiment environment and move of focus in experiment set B

Figure 5. Photo in experiment set B
3.4. System architecture

In this experiment we have three sets. But there are only two parts of difference: display of layout and media of learning companion. For the ease of implementation of three experiment sets, we decide to use the same database and modules. The advantages of this architecture are resources sharing, central data management, and variables controlling.

The system architecture with four modules and two databases (as shown in figure 6) are briefly described below.

Quiz database: all the quizzes of each stage are stored in this database.

Quiz module: this module requests quizzes from quiz database and display the quiz in proper size and style in different experiment set.

Answer module: answer module arranges the answer panel in each experiment set and send the results of each quiz to database.

Student database: this database collects the results and time of the subject spent on each quiz.

Emotion script: emotion script recorded every Aibo’s actions and video.

Motion module: motion module follows the emotion script and sends commands to Aibo. Aibo will be activated after receiving the command from this module.

Figure 6. System architecture

“Time” is the first priority in the system and experiment. We used two computers and a robot in experiment, many problems resulted for the accuracy of time calculation. Redundant time consumption mainly takes place at three situations: 1. handshake between computers and robot 2. synchronization of two computers and 3. activation of robot companion. With the experiment of trial and error, we determine the flow and sequence of system and make some error dealings to prevent any mistake that could happen during handshake and activating of robot companion (as shown in figure 7). The fourth and fifth step of sequence is a mechanism for the error handling of the system. The purpose of fourth and fifth step of the sequence is to prevent the situation that users send a lot of commands when Aibo is activating. The quiz module and answer module only receive commands from users if Aibo finished its actions. The other mechanism is that we segment the experiment into smaller sections. System will calculate the start time of each quiz, this will lessen the problems of miscount and improve the accuracy.

![Figure 7. Sequence of the system](image)

4. Results

In this experiment, there are three factors related to level of engagement were evaluated. We will discuss the results and these three factors: confidence of engagement level, concentration, and consistency.

4.1. Confidence of engagement level

According to two questionnaires we found that there was obvious increasing of level of engagement. Mathematic teaching and training in the environment such as environments of this experiment can make students avoid a lot of mistakes that made when they are in distraction \(F(1,47) = 35.4248 \ p<0.001\). The mean accuracy in this experiment also rose up from 52.33% to 73%. About the promotion of engagement in experiment set A and B, no significant difference between them \(F(1,30)<1 \ p=0.996\) were found. The results from questionnaires indicated that the game facilitate students' motivation and gain their attention (mean value of questionnaire is raised up from 3.176 to 3.891). Obviously students devoted themselves in the game. We observed their status of engagement via this game.
Table 2. Confidence of engagement level (Mean value of three sets)

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
<th>Variation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control set</td>
<td>2.9583</td>
<td>3.6333</td>
<td>+0.675</td>
<td>0.0037</td>
</tr>
<tr>
<td>Experiment set A</td>
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<td>4.0196</td>
<td>+0.5593</td>
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</tr>
<tr>
<td>Experiment set B</td>
<td>3.1099</td>
<td>4.0203</td>
<td>+0.9104</td>
<td>0.0035</td>
</tr>
<tr>
<td>Mean of three set</td>
<td>3.1761</td>
<td>3.8911</td>
<td>+0.7149</td>
<td>0.0011</td>
</tr>
</tbody>
</table>

4.2. Concentration

According to log file [19] and video tape observation, we analyzed the process recorded by video tape [20]. The mean value of students’ concentration has shown in figure 8. We can see that experiment set B is within large proportion of level of concentration. The move of focus in experiment set A is on a flat and experiment set B is a space. Before the experiment, we have an assumption that experiment set B will have less proportion of concentration because the move of focus in experiment set B is more complex than that of set A. This may cause participants distracted during the game. However after the experiment what we got is contrary to our assumption: experiment set B had higher rate of concentration compared with experiment set A. Although experiment set A was with simple moves of focus, participants were distracted and their focus stays in other place outside the computer which has the virtual companion inside. Their focus stayed on matters irrelevant to the experiment.

Figure 8. Results of concentration (Mean value of three sets) [F(2,44)=107.44 P<0.001]

4.3. Consistency

As the results showed, participants in experiment set A stayed longer time in the game with the concentration rate is about 20% lower than experiment B. We propose an extension on the definition of consistency here. One definition of consistency is the length of concentration time, and the other is the time they spent in the task. Although the distraction time of experiment set A is longer than in the other two sets, in the distraction time is gradually accumulated in the process of experiment. In other words, it was not in a continue block of time. Figure 9 is the summary of concentration time and distraction time. It indicated that they were distracted the participants went back to their task and concentrated again. So in this experiment we may conclude that participants paid more time in the game with the virtual companion.

Figure 9. Results of consistency (Mean value of three sets) [F(2,44)=12.4790 p<0.001]

4.4. Interview

Besides observations and data analysis we had also interviewed participants in two experiment sets in order to explore their thoughts about the experiment concerned with companion. We got a conclusion that how participants perceive their companion is a factor that effect students’ engagement. Some participants (62.5% of experiment set A) with less distraction time in experiment set A consider the virtual companion in the screen as a real companion. Other participants (37.5% of experiment set A) think the companion is an avatar of the program that is just like an assistant of Microsoft Office.

5. Conclusion

Although no participant considers the companion as part of computer program in experiment set B, there are things that deserve our attention. The robot companion may bring us some novel and physical interaction, but this holds true only the situation that robot is well coordinated with teaching materials, learning environment, and context. If the robot is not coordinated with the whole environment, the participants will treat the robot as just a machine next to a computer.
We can not make a firm conclusion on which type of learning companion is better for students. There are many factors that need to be considered in the later experiments when exploring the different between virtual and physical learning companions. First, we have a simple observation about the difference of engagement between virtual and physical learning companions which suggesting for further research and design method in this field. It is easier to implementing a virtual learning companion than to catch students' attention. Therefore we can focus on changes of the appearance of companion (such as pets, animals, and cartoon characters). In addition, the way companion accompany the students is not like a stuff occasionally appeal in the screen or stay at somewhere of the screen. Rather the most import thing of designing a virtual companion is the coordination among various kind of learning materials. The virtual companion is a companion that accompanying students and helping them understand the learning content. To implement a robot companion (physical companion) is much harder than a virtual one, but the robot companion has the advantage of appearance and a tangible shape. If we can make good coordination among the robot companion, context, learning material, and environment, it is believed that robot companion will be the next trend of learning companion.

6. Future work

After the comparisons we learned that there are some influences on students’ engagement. Virtual companion and robot companions have different influence on students. In both experiment sets, students are more easily been attracted then before. Under experiment set A, subjects have higher consistency time and experiment set B have higher rate of concentration. Both virtual and robot companions promote learning motivation and will be a good role for catch students’ attention. Although we have found immediate effect in this short term experiment, our next step is to try to extend the duration of using robot, and compare the effect among experiment sets.

In this experiment, Aibo is just a typical pet-type robot. We have not use sensors that were equipped on it. In the next phase of experiment we will use learning companions with sensor-equipped to explore the different influence between tangible robot companion and robot companion. In the future, we consider to equip robot companion with sensors in order to detect learners’ status such as their emotion, speech, gesture, body movement, heart beat, and body temperature in the experimental environment. The more information we get from the multiple senses of the student, the more data we can analyze, which, in term, provides more insights in how to promote the interaction between learners and learning companions.

7. References


