Experimental Verification of "Peer-ness" Formation by a Learning Companion Robot

—Possibility of inducing a sense of competition through long-term nonverbal interaction—

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Abstract: The purpose of this study is to construct a companion robot behavior model that provides a learning environment enhancing learners' motivation to learn by inducing peer awareness. Particularly, inducing "peer-ness" through robot behavior has an impact on education. Therefore, we verified a robot behavior model oriented to induce "peer-ness," including inducing a "sense of competition," through long-term nonverbal interactions. The results of this study confirmed the "Peer-ness" induction and demonstrated the validity, although it varied depending on the mental state.

Keywords: Peer learning, learning companion robot, non-verbal-communication

1. Introduction

With the development of information technology, the GIGA school concept was launched in Japan. Consequently, a form of teaching and learning known as e-learning has become more common. In addition, a rapid increase in the demand for e-learning was observed during the COVID-19 pandemic. However, the form of learning support in e-learning is dominated by support from a learner who is more knowledgeable about the learning domain than the learner who is better suited to transferring knowledge and facilitating understanding. However, there exists significant learning (peer learning), in which knowledge is consolidated and confirmed through collaboration with classmates. This learning, represented by active learning, is flourishing in school environments. Therefore, although Peer Learning is not conducted in on-site e-learning environments, it is limited to creating a single-person learning environment. However, Peer Learning has a positive impact not only on learning effectiveness but also on learner psychology (Marder, et al. (2017). Therefore, we aim to construct an e-learning environment that brings about a positive psychological effect of Peer Learning by using a learning support robot and investigate the possibility of inducing a sense of camaraderie (peer-ness) through the robot.

1.1 Peer Learning and Learning Support Robots

Research has been conducted on learning support robots. Kashihara (2019) showed that, unlike other media, learning support robots, which have physicality, can achieve more natural and authentic communication with learners. Hence, it is expected to reduce negative emotions such as learning inhibition. In a study using a computer as a companion in a learning environment, Kasai et al. (1999) developed a multi-agent learning environment in a cooperative learning environment that supports learning by using the companion as either a peer or teacher, depending on the learner's situation. A multi-agent learning environment was developed in a cooperative learning environment. Chan (1991) pointed out that a companion robot that behaves as a teacher may give the impression of being "watched." However, Marder et al. (2017) suggested that the presence of a peer can produce positive effects. In general, while previous studies on peer learning and learning support by robots have suggested their usefulness, they have not considered the feeling of "being monitored" that a teacher-like position brings. Therefore, this study aims to construct a "robot behavior model that induces peer-ness," oriented toward the construction of robots that exhibit only appropriate peer positions in response to various situations.

1.2 Intrinsic Motivation and Nonverbal Information

Numerous studies have examined the positive effects of intrinsic motivation on learning. Regarding autonomy-induced behavioral decisions related to intrinsic motivation, Yokoyama et al. (2009) stated that others' intention estimations influence one's own behavioral decisions. Osawa (2014) found that the behavior of the target induces intention estimation; anthropomorphism is used to superimpose the limb movements of the robot behavior on the movements of human limbs, and intention estimation from the target's behavior is performed by anthropomorphizing the target. Our study aims to boost learner autonomy through intentional inference from a robot's behavior and foster intrinsic motivation using nonverbal anthropomorphic cues. The robot's behavior model excludes linguistic information and relies solely on nonverbal cues, including nonsense utterances.

1.3 Short-term study of induction of "Peer-ness" by robot motion

We have experimentally clarified the mental factors that constitute the Peer-ness of learners during learning and created a psychological model with a hierarchical structure (Figure 1)(Koki (2022)). The meaning of each factor is listed in Table 1. The higher the evaluation value of each, the higher the impression of the psychological factors that exist at the top, and the more "Peer-ness" is felt in the end.

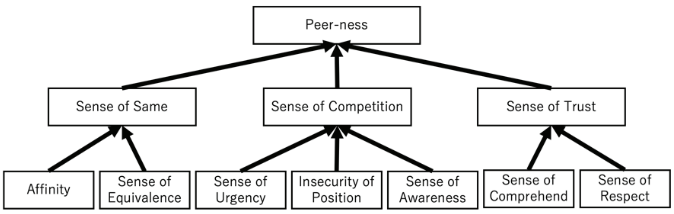

Figure. 1 Psychological model of feeling peer

Table 1. Each element of the psychological model and its meaning

factor	Meaning
Sense of Same	Feel as if companion is in the same situation and condition as you
Sense of Competition	Feel as if companion is competing with you
Sense of Trust	Feel that the companion is trustworthy
Sense of Affinity	Feel the closeness
Sense of Equivalence	Feel you and companion are of equal ability
Sense of Urgency	Feel an imminent gap in ability between you and companion
Insecurity of Position	Feel the state of being pulled out - pulled in
Sense of Awareness	Feel somewhat concerned about it.
Sense of Comprehend	Feel you and companion understand each other.
Sense of Respect	Feel that companion has superior capabilities

In an attempt to induce "Peer-ness" by robot actions according to the created psychological model, we investigated the relationship between robot actions and the psychological model, and based on the obtained results, we conducted a short-term study on inducing "Peer-ness." However, no strong results were obtained for inducing "Peer-ness" based on the "sense of competition" and "sense of competition," which are severely generated instantaneously, suggesting the need for a long-term study.

2. Method

This long-term study aims to induce a sense of competition and peer-ness, building on the findings of short-term studies. Owing to data limitations, the participants included one male junior high school student with basic learning abilities and four university students (two men and two women) commuting to Tokyo. This study focuses on the results of an experiment with junior high school student. The robot behavior and psychological model used were based on previous research (Koki, 2022), which led us to conduct a long-term interaction impression evaluation experiment with junior high school students with diverse developmental abilities in Tokyo. Referring to Kanda et al. (2004), we created episodes showing robot behavior corresponding to situations that were assumed to induce a "sense of competition, " based on the data obtained in previous experiments. Additionally, the robot was instructed to perform mathematical learning in conjunction with it. The experiment was conducted three times a week for two weeks for one hour per day, referring to Marder et al. (2017) and Kanda et al. (2003), who studied long-term interactions. Figure 2 illustrates the experimental flow and Table 2 presents the details.

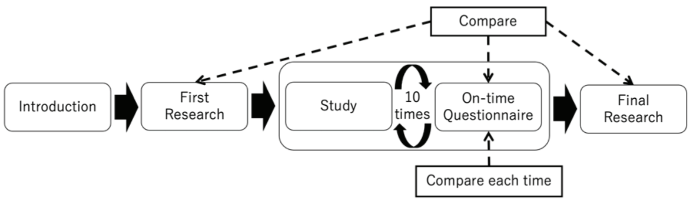

Figure 2: Experimental flow

Table 2. The details of the experiment

	detail
Introduction	Introduce about this experiment
First Research	Research about character (age, sex, motivation of math study, impression of robots [7]) and skill of math
Study	Three sessions in one study In one session, the robot performs (cause sense of competition) after one mini test The test has 3 levels(low-middle-high) decided by the result of First Research First session: low level test Second session: high level test Last session: middle level test
On-time Questionnaire	Administered immediately after the experiment to assess impressions of "Sense of Competition" and "Peer-ness", willingness to learn, and impressions “Sense of Competition” and “Peer-ness”: Evaluation by Vas method and Comparison with the previous study
Final Research	A questionnaire survey Administered to learners, asking them to rate their impressions of "competitiveness" and "peer" as well as their feelings about learning on a scale of 1 to 10

In addition to the experimental flow, interviews were conducted at the end of each day to gather the participants' impressions of the robot and their learning. The study focused on individual learning in an e-learning environment with the subjects and experimenter in separate spaces divided by an impulse screen. To maintain a sense of solitude during the study, learners received instructions from a third person and worked alone, answering exercises on loose-leaf paper while being monitored using a wearable camera. The actions of the robot were presented using the Woz method based on the episodes created.

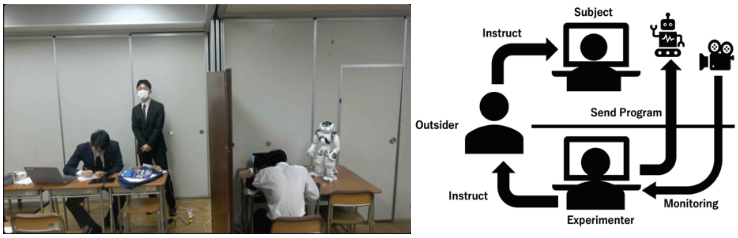

Figure 3: Schematic diagram of the experiment and environment

3. Result

3.1 Relationship between "Peer-ness" and "Sense of Competition"

The graphs illustrate the transition of the impressions of "peer-ness" and "competitiveness," respectively. The vertical axis indicates the score obtained using the VAS method converted to a perfect score of 100, and the horizontal axis indicates the number of experiments performed. The experimental days are indicated by red lines in figure 4.

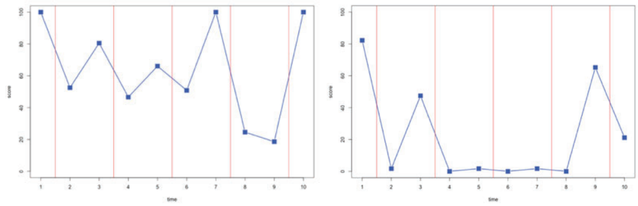
Figure 4: Impression evaluation results for "Peer-ness" (L) and "Sense of competition" (R)

Figure 4 indicates that the "Peer-ness" impression score remained high throughout all sessions, and the effect on "sense of competition" was unclear. However, "Peer-ness" score was notably lower at the 8th and 9th times, coinciding with participants expressing confusion about robot actions during interviews. After the experiment, participants mentioned feeling more similar to their peers, suggesting the potential induction of "peer-ness" during the study. Graphs indicate increasing impressions of "peer-ness" and "competitiveness" with each experimental day. This suggests a positive correlation between "competitiveness" and "Peer-ness" increase over time, though the connection throughout the day was not consistently strong.

3.2 Motivation to Learn Mathematics

This section describes the changes in the participants' willingness to learn mathematics observed throughout the experiment. In the pre-survey, participants were asked to rate their willingness to learn mathematics on a 10-point scale. The initial score was eight (on a 10-point scale). However, in the last day's interview, the students reported that they tended to give up without solving written answers in the early days. Hence, as an initial situation, willingness to learn mathematics depends on the problem being addressed. The following describes the content of the questionnaire feedback section from the last session of the experiment.

I really want to do math problems now!
It was fun to solve the problems so easily.
I was happy that the robot was kind to me.

Figure 5: Impressions after the 10th session

This suggests that the students were more motivated to learn mathematics throughout the experiment. In addition, to confirm their reflections throughout the experiment, we focused on the contents of the feedback column in the final survey. The actual content is presented below.

> I used to think that robots were something that would one day destroy humans (due to anime and Kamen Rider).
> But now I feel that robots can get along well with humans.
> I have grown attached to robots.
> Solving computational problems has become more fun than before.

Figure 6: Contents of the Final Research Comments Section

These results suggest the aforementioned suggestion of increased motivation is stronger.

3.3 Change in Robot Impressions

In this experiment, the participants were asked to answer questions about their impressions of the robot in a questionnaire survey after each experiment and in an interview survey after each experimental day. The results revealed that after repeated interactions, the participants began to judge the robot as a human being. Below are the results of the first and fourth interviews, and the results of the interview on the third day (after the fifth interview), in which changes were particularly evident.

> The applause for the first robot made me very happy.
> Maybe that's why I was a little disappointed that the second time it did so-so. However, I was very happy when the robot gave me a "〇" at the end.
> I'd like to solve the 2nd question one more time because I think I can solve it. I think I can do it.

Figure 7: Impressions after the first session

> The first round of applause seemed to be done by an adult. It was as if they were saying, "Mm, well done."
> The second round of applause looked like a friend on my side. It seemed as if he was saying, "Well done.
> The third time, he was embarrassed (?). The third time, she was making an embarrassed (?) motion, but I couldn't understand it well.

Figure 8: Impressions after the fourth session

> (Test subject) I guess so...the robot is starting to look more and more like a human after all.
> (Experimenter) Human...I see...
> (Test subject) I see... I was surprised that the robot was moving at first, but now it seems normal and natural...yes.

Figure 9: Day 3 Interviews

The results of the interviews indicate that, for the first time, the learners began to see the robot as a human being, something that had not occurred before the second day of training. The results of the questionnaire survey indicated that the robot began to guess what it wanted to say to learners.

4. Discussion

The following two points are important inferences from the results of this experiment.

- There is a proportional relationship between the "sense of competition" and "Peer-ness" ratings over the course of a day.
- Induction of intention estimation by presentation of nonverbal information

4.1 A Proportional Relationship between the "sense of competition" and "Peer-ness" Ratings over the Course of a Day

The results of this experiment indicate that there was no improvement in each of the "competitiveness" and "peer-ness" ratings throughout the entire 6-day experiment. However, the results of the experiment indicated that the two factors improved proportionally. This suggests that the robot's nonverbal information may induce a sense of competition as well as peer-ness, however, it also suggests the possibility of a decrease in the evaluation of the robot as days passed. This could be due to the effects of day-switching, the cause of which remains unclear. Therefore, the effects of switching days should be further investigated.

4.2 Induction of Intention Estimation by Presentation of Nonverbal Information

The questionnaire and interview survey results indicated an increase in participants' motivation to learn mathematics throughout the experiment. This increase may not be solely attributable to improved self-efficacy through repeated learning, as problems of varying difficulty were consistently presented with some remaining unanswered within the time limit in each session. Additionally, Figures 7 and 8 depict a growing perception of the robot as human, suggesting a thought process akin to "anthropomorphism" based on Osawa (2014). The results indicated that the robot infers its intentions through the exhibited movements. Moreover, the robot's behavior starts from the learner's exercise-related information, potentially triggering an active strategy and decision-making related to the "autonomy" component of intrinsic motivation. This increase in autonomy may lead to enhanced intrinsic motivation. Additionally, learners' self-affirmation increased when they believed they could solve problems the next time, further supporting their intrinsic motivation.

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