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Effects of Collaborative Learning between Educational-Support Robots and Children who Potential Symptoms of a Development Disability

Felix Jimenez
Graduate School of Engineering,
Nagoya University, Japan
Email: h208042@gmail.com

Tomohiro Yoshikawa
Graduate School of Engineering,
Nagoya University, Japan
Email: yoshikawa@cse.nagoya-u.ac.jp

Takeshi Furuhashi
Graduate School of Engineering,
Nagoya University, Japan
Email: furuhashi@cse.nagoya-u.ac.jp

Masayoshi Kanoh
School of Engineering,
Chukyo University, Japan
Email: mkanoh@sist.chukyo-u.ac.jp

Tsuyoshi Nakamura
Graduate School of Engineering,
Nagoya Institute of Technology, Japan
Email: tnaka@nitech.ac.jp

***Abstract*—With the advancement in robotics, more attention has been paid to the development of educational-support robots that assist in learning. Although most existing studies report the effects of collaborative learning between educational-support robots and healthy children, since the number of children with developmental disorders in primary schools has increased annually, it is necessary to develop educational-support robots for children with development disorders. Therefore, a recent study developed a robot that teaches children with developmental disorders. However, existing studies do not reported educational-support robots for children who have potential symptoms of a development disability, also referred to as "gray zone children." This study investigates effects of collaborative learning between robots and gray zone children. In collaborative learning, the child and the robot alternately read aloud one page of teaching material. These children have symptoms similar to ADHD and difficulty learning over long periods of time. The robot is designed to work by the Wizard of Oz method and interacts with children in real time.**

I. Introduction

The growth of robot technology has prompted the increasing interest in educational-support robots that assist in learning [1]. For example, an educational-support robot can support students throughout their school life [2] or help them learn English [3]. Moreover, Koizumi [4] developed a robot-directed series of Lego block building classes intended to promote spontaneous collaborations among children. The robots facilitated collaborative learning among the children and established positive social relationships with these children by praising their efforts. These experimental results suggest that, in addition to stimulating spontaneous collaboration, robots can enhance children's enthusiasm for learning. Thus, our work contributes to the existing literature in that the robot prompts the learner to improve their motivation for learning and promotes collaborative learning.

Most existing studies report on the learning effects of collaborative learning between educational-support robots and healthy children. However, the number of children in primary schools who have been diagnosed with developmental disabilities has increased [5]. These children have difficulty communicating with other children and learning for an extended time. Therefore, the development of educational-support robots for children with developmental disorders is an important undertaking. Among studies focusing on children with autism, one proposed a support methodology that stores the medical knowledge of the child with a developmental disability [6]. Another study developed a learning support system for these children [7]. A recent study developed a robot that teaches children with developmental disorders and reported that the robot prompted effective learning [8].

In the Ministry of Education of Japan, a patient with a major developmental disability is considered to have one of the following conditions: high-functioning autism, learning disabilities, or attention deficit hyperactivity disorder (ADHD) [9]. A child with autistic disorder often has difficulty interacting with others in a social environment. A child with high-functioning autism has even more difficulty socially interacting with others. A child with learning disabilities has a low learning ability. Therefore, they have difficulty acquiring new knowledge. A child with ADHD cannot stand still. For example, they often run around in the classroom. One recent study reported that the robot can prompt the child with learning disabilities to improve its concentration and collaborative learning [8]. Moreover, a recent study that focuses on children with autistic disorder found that educational-support robots promote learning [10].

However, existing studies do not reported educational-support robots for children who have potential symptoms of a development disability, also referred to as "gray zone children." Although gray zone children are not diagnosed for development disorders by doctor, they can have symptoms similar to children with developmental disorders. Therefore, gray zone children have difficulty learning over long time peri-

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Fig. 1. Ifbot

Fig. 2. Remote system

ods similar to children with developmental disorders. We think that collaborative learning with robots is a good method for increasing the learning time of gray zone children. Additionally, educational-support robots prompt the child with learning disabilities to improve their concentration and collaborative learning ability [8]. Thus, they can learn for an extended period of time.

This study investigates effects of collaborative learning between robots and gray zone children. In collaborative learning, the child and the robot alternately read aloud one page of teaching material. These children have symptoms similar to ADHD and difficulty learning over long periods of time. The robot is designed to work by the Wizard of Oz method and interacts with children in real time. If the robot joins in collaborative learning between gray zone children, we think that gray zone children take an interest in the robot and increase their learning time.

II. Overview of Robot

The robot used in this study is an Ifbot (Fig. 1). Ifbot is a conversational robot that can be used to support learning and promote effective learning [14]. This robot has a limited number of expressions and does not move its arm and body. The experiment reported in this study was conducted using the Wizard of Oz method. Therefore, we used a remote system (Fig. 2) to control the robot's expressions, which are limited to expressions of happiness and sadness. Each expression has 12 patterns and the experimenter's voice is converted to the robot's voice through a PC.

In the collaborative learning portion of this experiment, the child and the robot alternately read one page of teaching materials aloud. Thus, the robot was designed to read s sentence slowly to ensure the gray zone children can comprehend the word.

III. Experiment

A. Method

We conducted the experiment in "Hikari Kids" that was established by "Gifu Emergent Research" of general incorporated association. Three or four gray zone children, who have potential symptoms of ADHD, and one teacher of Hikari Kids participated in the experiment. Two researchers operated the robot remotely from a separate room.

The robot and children engage in collaborative learning while the teacher observes. The children and the robot receive a lesson on the history of Japan from two comics in a 30 minutes learning session. During one of the learning sessions, referred to as "Himiko learning sessions," a comic is read that tells the story of Himiko, a Japanese queen [16]. The other learning sessn, referred to as "Nobunaga learning sessions," tells the story of Oda Nobunaga, a Japanese samurai [17].

Three gray zone children participated with the robot in the first Himiko learning session, but the robot was absent in the second Himiko learning session. To avoid the effects of order, four gray zone children learned without the robot in the first Nobunaga learning session. In the second Nobunaga learning session, three gray zone children learned with the robot. Each learning session was conducted over a three week period. Both children and teacher were ordered to read different chapters of the comics in each learning sessions. Moreover, we mode video recording of gray zone children learning with the robot to investigate how they associate with the robot in each of the learning sessions.

B. Evaluation

To evaluate the effects of collaborative learning between gray zone children and the robot, we applied three different criteria. The first was learning time, defined as the time that all gray zone children learn while sitting down in an experiment. For example, if one gray zone child refuses to sit down and learn with the other children or robot, the learning time does not accumulate. If all gray zone children sit down and learn with other children or the robot, the learning time is counted.

The second criteria was running time, defined as the number of times during the collaborative learning session that gray zone children get up and run around without learning.

The third criteria was breaking time, defined as the time gray zone children do not learn during an experiment. The

(a) Learning session with a robot.

(b) Learning session without a robot.

Fig. 3. Experimental conditions

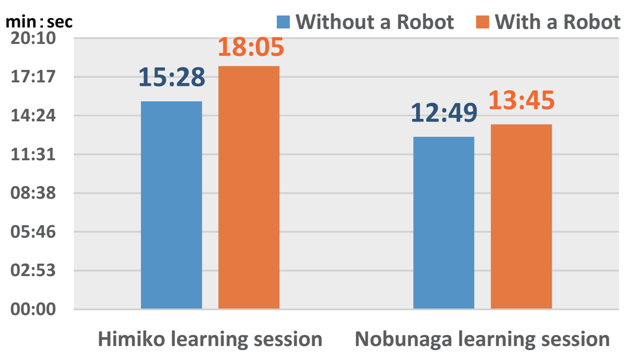

Fig. 4. Learning time of each learning sessions

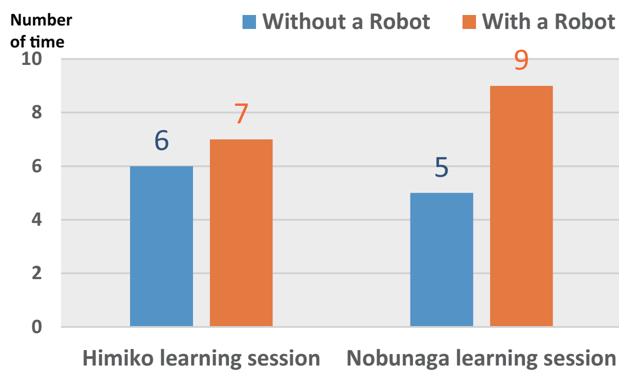

Fig. 5. Running time of each learning sessions

breaking time is considered adverse learning time. For example, if one or more of the gray zone children run around the classroom without learning, the breaking time was counted. If all gray zone children sit down and learn with the other children or robot, the breaking time was not counted.

The Hikari Kids' teacher stated that the gray zone children of this experiment are often rampant in the classroom. Therefore, we confirm that the robot can encourage these children to improve their concentration through a comparison of the learning, breaking, and running times between learning sessions, with and without the robot.

C. Result

The experimental conditions are shown in Fig.3. The learning times are shown in Fig. 4. The Himiko learning session is shown on the left and the Nobunaga learning session is shown on the right. The blue graph indicates each learning session without the robot. The red graph indicates each earning session with the robot. Figure 4 indicates that the learning time of each learning session with the robot is longer than each learning session without the robot. Moreover, when we assessed the video of the collaborative learning session, we found that one child scolds another child who runs around, and prompts him/her to join in learning with the robot.

The running times are shown in Fig. 5. The Himiko learning session is shown on the left and the Nobunaga learning session is shown on the right. The blue graph depicts each learning session without the robot. The red graph indicates each learning session with the robot. Figure 5 indicates that the running time of each learning session with the robot is higher than each learning session without the robot. However, we found that gray zone children support the robot. For example, one child might say something similar to "I will fetch a book for the robot" or "I will bring the table so that the robot can read a book." This is the reason for the high running time

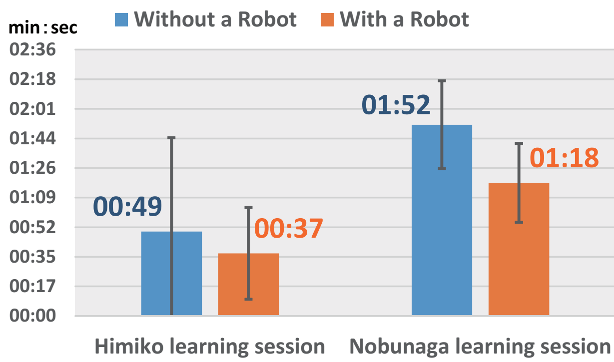

Fig. 6. Average breaking time of each learning session

with the robot during the learning sessions. In fact, gray zone children stand up for the robot three times during Himiko learning session and four times during Nobunaga learning session.

The breaking times are shown in Fig. 6. The Himiko learning session breaking time is shown on the left and breaking time durong the Nobunaga learning session is shown on the right. The blue graph represents each learning session without the robot. The red graph represents each learning session with the robot. Figure 6 indicates that the breaking time of each learning session with the robot is lower than learning sessions without the robot. Moreover, we found that gray zone children remain seated when the robot reads a comic.

Therefore, if the robot collaboratively learns with the gray zone children, the robot improves the children's ability to concentrate and the time over which they learn.

IV. Discussion

The experimental results suggest that the robot encourages children with ADHD like symptoms to improve their concentration during collaborative learning. In fact, we determined that the learning time during a collaborative learning session increases compared to a collaborative learning session without the robot. While the gray zone children studied here are often rambunctious in the classroom, they tend to stay still and learn a lot more efficiently in the collaborative learning sessions with the robot than without the robot.

We propose one reason for the improved concentration of gray zone children during the collaborative learning sessions with the robot: its presence. A robot's presence can attract humans [18]. An example study of the effect of a robot's presence is in Shiomi's study [19]. Shiomi reported that some children tended not to listen to a robot explaining a museum display in the beginning. However, when the robot explains a display that is interesting to the children, the children tend to pay closer attention to the robot's voice. Moreover, Koizumi's study reported that healthy children tend to pay more attention to a robot's voice during collaborative learning. We infer that a similar situation occurs here for gray zone children in the presence of the robot. Moreover, we found that gray zone children stand still when the robot reads a comic. We think that the robot's presence can attract gray zone children. Therefore, the robot encourages gray zone children to improve their concentration while collaboratively learning.

V. Conclusion

This study investigated the effects of collaborative learning between a robot and gray zone children. While collaboratively learning, the child and the robot alternately read aloud one page of the teaching materials. Gray zone children, who exhibit symptoms of ADHD and have difficulty learning over extended periods of time were studied here. The robot was designed to operate based on the Wizard of Oz method and interacts with children in real time.

The results of this study suggest that the robot prompts gray zone children to improve their concentration while collaboratively learning. Moreover, we found that the learning time increased during the collaborative learning session in the presence of the robot than without the robot. While the gray zone children studied here are often disorderly in the classroom, they tend to stay still and learn a lot more efficiently during the collaborative learning sessions with the robot than without the robot.

In future work, a longer-term experiment will be conducted to investigate the psychological and learning effects of collaborative learning between a robot and gray zone children.

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