Tricycle-style Operation Interface for Children to Control a Telepresence Robot

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Abstract

Telepresence robots will provide significant value to childhood education. They will offer children opportunities to join remote classrooms and to communicate with speakers of different languages in more enriched ways than are available by conventional video conferencing. However, the introduction of child-operated telepresence robots has yet to be tested. The design of the operation interface presents a particular challenge. In this study, we report the development of a tricycle-style operation interface based on requirements identified through classroom field observations. It was designed for intuitive use, even by young children, without the need of detailed instruction. The usability of the interface was tested in a field experiment involving 20 participants (4–8 years old). The participants were asked to perform six elementary tasks using a telepresence robot system controlled either by the tricycle-style interface or a standard video-game controller. The operational performance of the tricycle-style interface was found to be superior to that of the standard controller. The advantages and disadvantages of both interfaces are discussed.

keywords: telepresence robot, children, remote communication, distance education, tricycle

1 Introduction

Telepresence robots are expected to provide next-generation remote communication media. By remotely controlling a robot that functions as an avatar of its human operator, the operator can physically interact with remote locations. By contrast, in conventional video-conference services, remote communication is interfaced only by a monitor screen. The robot can navigate remote locations and manipulate physical objects using its actuators. One of the first studies of telepresence robots involved the concept of telexistence [1], pioneered by Tachi in the 1980s. This study inspired the development of a wide variety of robotic systems incorporating advanced virtual reality technologies. On the other hand, companies have recently begun commercializing telepresence robot products [2–5]. Most of the telepresence robot products were designed as extensions of video-conference services, with a PC screen installed on a movable base. Such products are currently used in locations such as hospitals and offices.

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A promising field for the application of telepresence robots is education. In fact, telepresence robot trials have already begun in elementary schools in South Korea [6] to compensate for the shortage of English teachers. The robots positioned in the classrooms were designed to be remote-controlled by native English teachers residing in their own countries. However, child-operated telepresence robot systems have yet to be tested. Telepresence robots would provide immense educational value by offering children opportunities to join remote classrooms and to communicate with people in remote locations, including foreign countries. Parents from non-native English speaking backgrounds have always desired such experiences for their children. As discussed in previous studies [7, 8], video conferencing alone provides children with limited communication options. While robot avatar platforms such as the Huggable [9] are designed for remote communications, these systems have not been tested on children between remote locations. Here we aim to provide children with enriched communication channels via a self-operated telepresence robot system. Since most classroom activities for young children involve physical objects such as educational toys, it is expected that even if a child is unfamiliar with the language used in a classroom, he/she could participate in the activities when offered physical access to objects.

In this study, we report the development of a child-friendly telepresence robot system. A major challenge of such a system is the design of the operation interface. Crucial requirements of the operation interface were identified from observations of daily classroom activities in an English learning school for Japanese children in Tsukuba City, Japan. The tricycle-style operation interface was designed to satisfy these requirements. Finally, the usability of the developed interface was assessed in a field experiment at the English learning school (4–8 years old). Designing a telepresence robot system with an operation interface for children is rendered difficult by the lack of field trials. Our field experiment, in which the tricycle-style interface was compared with a standard video-game controller, bridges this knowledge gap. A part of the experimental results reported in this paper (Section 5.1) has been presented at a symposium [10]. In this paper, we summarize the whole study with describing the development of the system and the results of a newly-conducted analysis (Section 5.2).

The structure of the paper is as follows. The design requirements are described in Section 2, while an overview of the developed telepresence robot system is described in Section 3. The field experiment conducted to assess the system and its results are presented in Sections 4 and 5, respectively. The results are discussed in Section 6, and the conclusions are presented in Section 7.

2 Design Requirements

The majority of classroom activities for young children involve physical objects such as educational toys. Therefore, even if a child struggles with a foreign language, he/she should be able to participate in educational activities when offered physical access to the objects (e.g., grasping an object and handing it to other people).

In 2011, we paid regular visits to a classroom of an English learning school for Japanese children (Minerva Language Institute Co., Ltd.) in Tsukuba City, Japan. The general goal was to explore whether robotics could support childhood education, including the use of a humanoid robot. Throughout the visit, we observed numerous types of lessons assigned to children aged 3–12 years. In addition, we regularly conversed with the teachers and parents of the children and requested their opinions regarding our research activities.

Our initial expectations were strongly supported by the observations and pilot trials. Children uncomfortable with English could participate in various educational activities conducted in English if granted physical access to educational toys via the control of a robot prototype. Simultaneously, the operation interface design was identified as very important to children of this age group. In particular, the following design requirements are preferably to be satisfied:

(1) Unrestrained movement of the operator: When operating a robot by remote control, a child should be allowed to move his/her whole body freely. This activity significantly relaxes the child, particularly during interaction with foreign language speakers.

(2) No operating manual is required: Unlike adult operators, young children cannot comprehend detailed instructions. Therefore, the operation interface must be accessible to young children with minimum verbal instruction.

(3) The operator feels a certain amount of friction when remote-controlling a robot: From a safety perspective, the interface should be sufficiently weighty to ensure non-negligible friction, thereby preventing a sudden large movement at the robot side.

(4) The basic interface is familiar: Given that the system aims to provide educational support for children in classroom or home environments, the use of special equipment is precluded; rather, the interface should comprise easily available and familiar equipment.

Based on these requirements, a tricycle-style teleoperation interface was designed as explained in the next section. By riding the device, children can easily remote-control a robot. Although motion-capturing devices such as Kinect satisfy requirements (1) and (2), we consider that requirements (3) and (4) are equally important. To this end, we exploited the tricycle as an operation interface.

3 Telepresence Robot System for Children

3.1 Overview of the System

Our telepresence robot system comprises an operation interface, a server PC that relays data, and a telepresence robot controlled from a remote location via the interface. As detailed in the succeeding paragraphs, we developed two types of operation interfaces and tested them in the field experiment explained in Section 4. Control signals sent from the operation interface were routed through the server PC and delivered to the telepresence robot. All transmitted signals were encrypted using SSH tunneling.

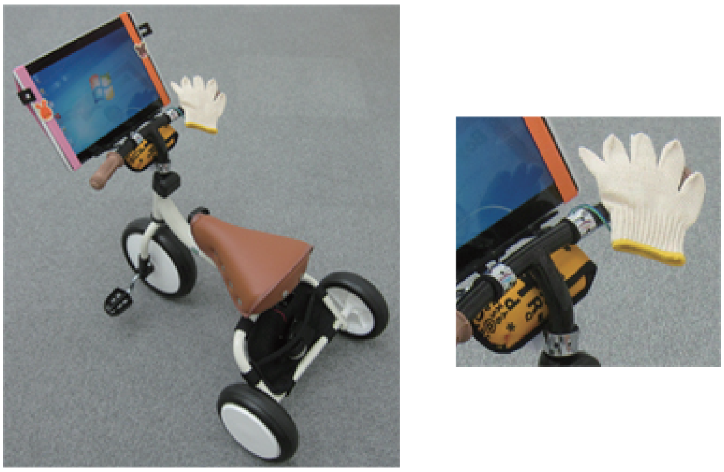

Figure 1: First prototype of the tricycle-style operation interface. Rider movements are detected by a 3-axis accelerometer embedded under the saddle, which is used to remotely control a robot. The operator can also remotely control the opening and closing of the robot's hand using a data glove. The robot is visible and audible via a tablet PC mounted on the handlebar.

3.2 Tricycle-style Operation Interface

Typically, a robot is remote-controlled using a joystick or a video-game controller equipped with a joystick function. As an alternative to such devices, we developed a tricycle-style operation interface in which the robot is controlled by whole-body movement. The first prototype, based on a commercially available tricycle, is pictured in Figure 1. Whole-body movement is detected by a 3-axis accelerometer embedded under the saddle. A tablet PC (magnified in the right image of Figure 3) is mounted on the handlebar of the tricycle. By running the video-phone software Skype on the tablet PC, the operator can observe and hear from a robot placed in a remote location. In addition, a data glove (right image in Figure 1) enables the user to remotely control the opening and closing of the robot's hand. The data glove is equipped with a bend sensor extending along the dorsal length of the middle finger. Daily classroom activities frequently require the use of hands; for example, the passing of an object to another person. Thus, the function of grasping objects is incorporated into our telepresence robot system. The accelerometer module and the data glove communicate with the tablet PC via a Bluetooth connection. The tablet PC then communicates with the server PC via the Internet.

From pilot tests conducted in the classroom (see Section 4.2), we concluded that more precise sensing was required to detect movements of the tricycle base. Such precision would enable even young children to remotely grasp an object and to hand it to someone in a remote location. The second prototype of the tricycle-style operation interface (Figure 2) is equipped with two rotary encoders (Baumer, 16.25W.5000-B2-5) on its rear wheels. The direction of movement is determined by calculating the difference between the rotations of both wheels. The tablet PC and data glove are those used in the first prototype. In another set of pilot tests, the second prototype functioned well when controlled by young children. Therefore, the second prototype was adopted in the experiment of Section 4.

Figure 2: Second prototype of the tricycle-style operation interface. The 3-axis accelerometer of Figure 1 is replaced by two rotary encoders affixed to the rear wheels of the tricycle. The encoders detect more precise movement of the tricycle base.

Figure 3: (Left) A video-game controller for the remote control of a robot. (Right) A tablet PC functioning as a Skype monitor screen.

3.3 Video-Game Controller

As mentioned in Section 3.2, robots are typically controlled by a joystick or a video-game controller equipped with a joystick function. This type of interface is familiar to the majority of adults and children. Therefore, a standard video-game controller (Microsoft Xbox 360 wireless controller; left image in Figure 3) is adopted as the baseline interface against which the tricycle-style operation interface is compared. The robot's movement is remotely controlled by tilting its joystick in a certain direction. The opening and closing of the robot's hand is controlled similarly, by pushing the "B" button on the video-game controller. The remaining buttons on the device are set to be non-operational. The operator is provided with the video-game controller and a tablet PC (ASUS Eee Slate EP121, right image in Figure 3). Similar to its role in the tricycle-style operation interface (Section 3.2), the tablet PC functions as a Skype monitor screen. During the experiment, the tablet PC was angled on the floor to capture the operator's face, irrespective of the operator's height (left image in Figure 8).

Figure 4: A telepresence robot remotely controlled by children. The operator's face is projected onto the laptop LCD screen using Skype. The robot is built on a Pioneer P3-DX mobile robot base and equipped with a 1-DOF gripper hand, both of which can be remotely controlled using either the tricycle-style operation interface (Figure 2) or the video-game controller (Figure 3).

3.4 Telepresence Robot

The telepresence robot was remotely controlled by children using either of the two operation interfaces described in Sections 3.2 and 3.3. The robot, built on a Pioneer P3-DX mobile robot base and equipped with a 1-DOF (open/close) gripper hand, is shown in Figure 4. For safety reasons, the arm is constructed from an elastic material that bends under sufficient force, and the fingertips are covered by sponges. The robot carries a laptop PC that locally communicates with the mobile robot base and the hand and remotely with the operation interfaces via the Internet. By running Skype on the laptop PC, humans surrounding the robot can see the face of a remote child operator and may converse over the laptop LCD screen. An external USB camera (Logicool Qcam(R) Orbit AF) is installed at the arm base position, enabling the operator to capture a good view of the entire hand. An external USB speaker (Olasonic TW-SS7) installed on the mobile robot base provides sufficient sound to the robot locality.

4 Field Experiment

4.1 Goal of the Experiment

To assess the usability of the tricycle-style operation interface and to guide the design of a child-friendly telepresence robot system, we conducted a field experiment. Participating children performed six tasks using two operation interfaces (the tricycle-style operation interface and the video-game controller). The usability of the system was assessed from both operator and robot sides. On the operator side, the average percentage of task completion within the time limit was analyzed. On the robot side, the behavior of an adult experimenter directing the children was analyzed.

Figure 5: The classroom in which the experiment was conducted. Participants were requested to control a robot placed in a remote room (Figure 6) using an operation interface. The classroom was located in an English language school (Minerva Language Institute Co., Ltd.) in Tsukuba City.

4.2 Experimental Setting

Two separate rooms were connected via the Internet. With the kind cooperation of the Minerva Language Institute Co., Ltd., which manages 600 English language classrooms in Japan, the experiment was conducted in a classroom in Tsukuba City. The room, shown in Figure 5, was approximately 25 m^2. Participants used both operation interfaces for remote-controlling the robot. The telepresence robot was housed in a 25 m^2 room located at the University of Tsukuba (Figure 6).

The experiment was undertaken by two experimenters. Experimenter-A was located in the English language school classroom with the participants. As will be explained in Section 4.5, this individual instructed the participants and ensured their safety during the experiment. Experimenter-B was based at the university with the telepresence robot that was remotely controlled by the participants on the classroom side.

4.3 Participants

Having received approval for this experiment from the Ethical Committee of the University of Tsukuba, we recruited participants by explaining and advertising our study to the parents of children attending regular classes at the Minerva Language Institute Co., Ltd. We obtained permission to include 20 children (4–8 years, 12 females; 8 males) in the experiment. Students at this English language school are regularly taught in groups; hence, participants were accustomed to this lesson style. Simultaneously, safety issues restricted the number of participants in each session. As a compromise, each experimental session involved two randomly chosen participants.

Figure 6: The room housing the telepresence robot. An adult experimenter (Experimenter-B) directed remote participants to perform six tasks by remotely controlling the robot. The room was located at the University of Tsukuba.

4.4 Experimental Design

A within-participants design was adopted, in which each participant used both operation interfaces sequentially: the tricycle-style operation interface and the video-game controller. To correct for the effect of order, half of the participants (5 groups; 10 participants) were assigned an experimental pattern A in Figure 7, while the other half were assigned an experimental pattern B. In each time slot, one participant used one operation interface to perform six tasks. The tasks are explained in the next section.

4.5 Procedure

At the beginning of each experiment, two participants were directed by Experimenter-A to enter the classroom (Figure 5). Experimenter-A randomly chose one participant to perform the experimental tasks first (Participant-1 in Figure 7). Experimenter-A provided instructions to each new participant each time a new operation interface was introduced. The instruction consisted of four parts: (1) Explanation that the robot was remotely controlled by the operation interface; (2) Demonstration of robot movement; (3) Demonstration of the opening and closing of the robot's hand; and (4) Introduction to Experimenter-B, visible on the LCD screen of the tablet PC. After providing instructions, Experimenter-A observed the participant from a short distance, with sufficient regard for the participant's safety.

Guided by Experimenter-B over the LCD screen of the tablet PC, the participant was asked to perform the following six tasks sequentially:

Task 1 : Hold a pen for 3 seconds using the robot's hand (task to be completed within 10 seconds).

Task 2 : Move the robot 0.3 meters backwards (task to be completed within 10 seconds).

Task 3 : Move the robot forward approximately 1.0 meter diagonally at approximately 35 degrees (task to be completed within 30 seconds).

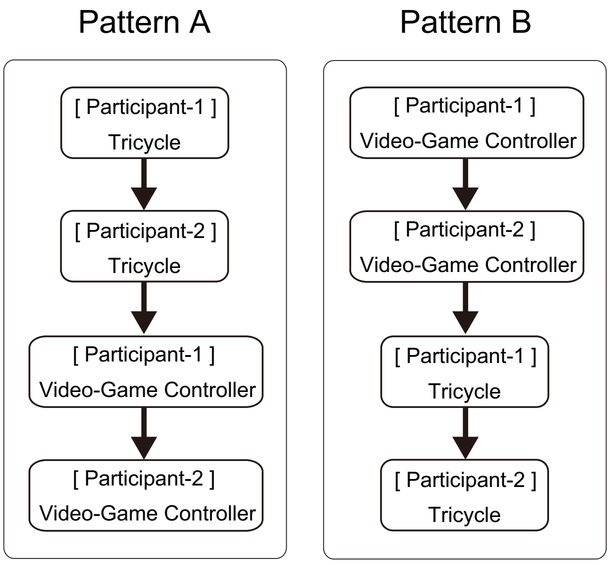

Figure 7: Flowchart of the experiment: 5 participant groups (10 participants) were assigned an experimental pattern A, while the remaining 5 groups (10 participants) were assigned an experimental pattern B. This design corrects for the possible effect of ordering.

Task 4 : Turn right or left at an angle of approximately 90 degrees (task to be completed within 30 seconds).

Task 5 : Hold a pen and deposit the pen in a box (task to be completed within 30 seconds).

Task 6 : Say “Thank you” after receiving an object from Experimenter-B (task to be completed within 10 seconds).

These tasks were designed to involve two fundamental controls of the robot. One is the two-dimensional locomotion of the robot base and the other is the hand movement of the robot. Being one of the most frequently handled objects, an ordinary pen was chosen as the physical object to be manipulated by the robot. Although the hand movement of the robot used in the experiment was significantly limited, more advanced robots equipped with more mobile hands are anticipated in the near future. Such advances would enable remote children to participate in classroom activities such as drawing.

Figure 8 is a snapshot taken during an experimental session. When all tasks were completed or the time limit had elapsed, Experimenter-A returned to the participant and asked the next participant to operate the robot. Once both participants had completed the tasks using both interfaces (according to Figure 7), Experimenter-A interviewed each participant before finishing the experimental session. The interview items were as follows:

- Q1: Which interface was more fun?
- Q2: Which interface was easier to use?

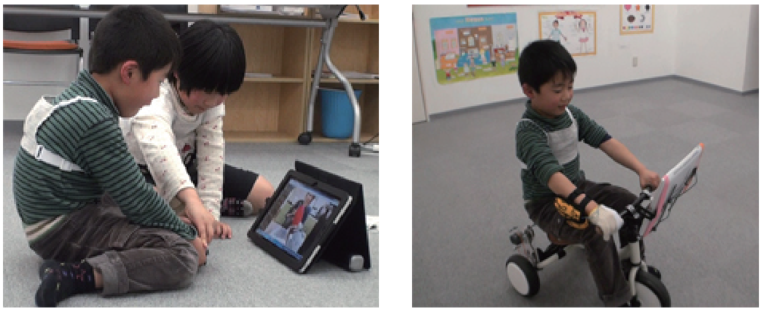

Figure 8: (Left) A participant using the video-game controller to remotely control the robot. (Right) The same participant using the tricycle-style operation interface.

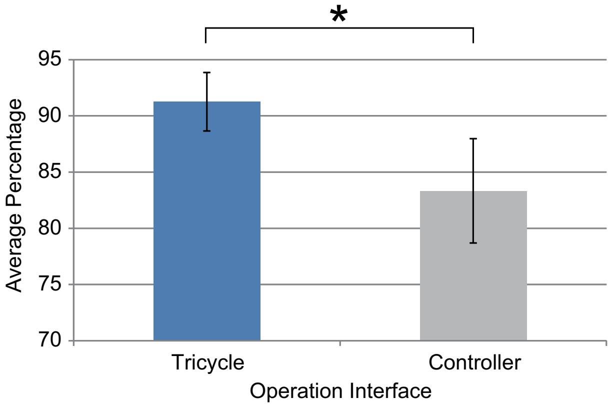

Figure 9: Task performance using two operation interfaces. Each bar represents the average percentage of tasks accomplished within the time limit using either of the two interfaces. The mean performances are significantly different ($p < 0.05$).

5 Results

5.1 Operator-side Perspective

Figure 9 shows the average percentages of the tasks that were accomplished within the time limit using either of the two interfaces. The average includes results for all 20 participants spanning all six tasks. The results show that when using the tricycle-style operation interface, the participants accomplished more tasks within the time limit than when using the video-game controller. The Wilcoxon signed-rank test revealed a significant difference between the two means ($Z(20) = -2.111$, $p < 0.05$).

Figure 10 shows the task performance for each of the six tasks. The tasks appeared to be relatively easy for the participants, but the performance was improved when the tricycle-style operation interface, rather than the video-game controller, was used. Using the tricycle-style operation interface, more than 80% of participants (on average) completed five of the tasks within the time limit. The most difficult task was Task 5, a combination task in which the operator was required to remotely control both the hand and the movement of the robot.

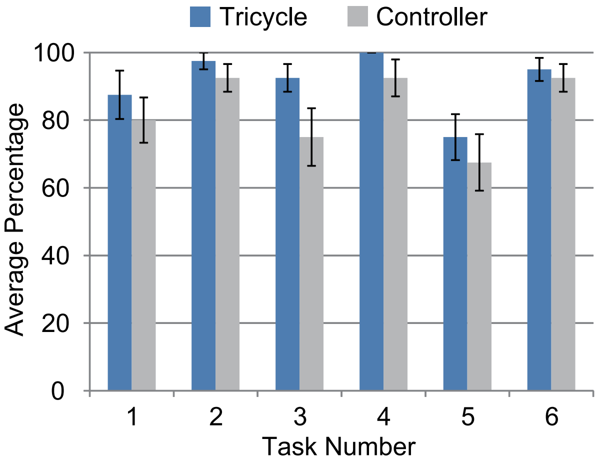

Figure 10: Task performance of each of the six tasks using the two operation interfaces (tricycle and video controller).

5.2 Robot-side Perspective

An important aspect of a telepresence robot system is its two-way operation; users communicate from the operator side and the robot side. This aspect will become particularly important in situations requiring collaborative tasking. Our experiment focused mainly on the operator side; therefore, participants were assigned to the operator side alone. Nonetheless, during the experiment, behavioral differences were observed in Experimenter-B, who interacted with the participants through the robot under both experimental conditions. More specifically, Experimenter-B spoke more often (particularly when repeating certain instructions) to operators using the video-game controller than to those using the tricycle-style operation interface. Indeed, once all experiments were complete, Experimenter-B reported that it was more difficult to guide participants using the video-game controller.

From videos taken on the robot side during the experiment, we extracted the statements spoken by Experimenter-B. The robot-side room was silent during the experiment; therefore, statements were easily extracted from the videos. From all such statements, we identified those that had not been specified on a pre-determined experimental instruction list assigned to Experimenter-B. These included the repetition of certain adverbs such as “more left, more left, ...,” involuntarily spoken by the experimenter. The frequency of these statements increased if the experimenter showed more difficulty in handling the situation. The results are summarized in Figure 11. As expected, Experimenter-B had spoken these words significantly more frequently to operators of the video-game controller than to operators of the tricycle-style operation interface ($Z(20) = -2.38$, $p < 0.05$).

5.3 Interview Results

Responding to question Q1, 11 participants selected the tricycle-style operation interface, while 9 selected the video-game controller. Question Q2 generated an even split between the tricycle-style operation

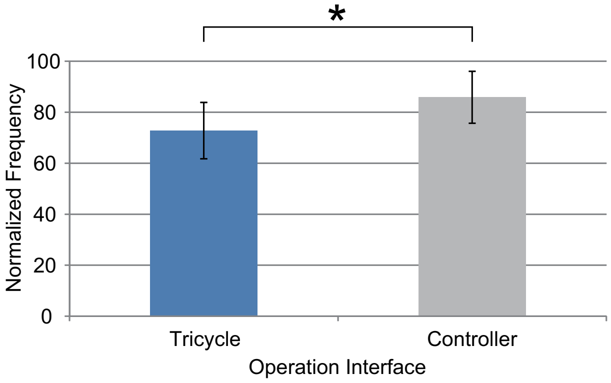

Figure 11: Total number of statements spoken by Experimenter-B that had not been specified on the pre-determined experimental instruction list. These statements appeared to increase in more difficult situations.

interface and the video-game controller. Therefore, participants showed no significant preference for either of the two interfaces.

6 Discussion

The experimental results suggest that the tricycle-style operation interface is more operable to participants than the standard video-game controller, for each of the six prescribed tasks. However, advantages and disadvantages exist in both interfaces, as summarized below.

The tricycle-style operation interface becomes inoperable when stuck near a wall. This issue is expected to be problematic, especially if the sizes or shapes of the rooms in which the robot and the operator are located differ considerably. Adaptive methodologies to control the gain parameter of the master-slave control would be required in such situations.

The video-game controller might better promote communication between the two participants than the tricycle-style interface. With the latter interface, participants surrounding the operator were required to follow the tricycle to visualize the display and to communicate with the operator. In the case of the video-game controller, both participants could share the display easily, as shown in the left image of Figure 8. In fact, in a follow-up video analysis, the bystander participant spoke more statements to the operator participant during the use of this interface (Figure 12).

Finally, we found no significant communication delay between the operator side and the robot side probably because both locations were in the same city, enabling strong network connection. When connecting classrooms over greater distances, communication delay could become an issue. Such situations may benefit from a virtual world simulator incorporated into the operation interface [11].

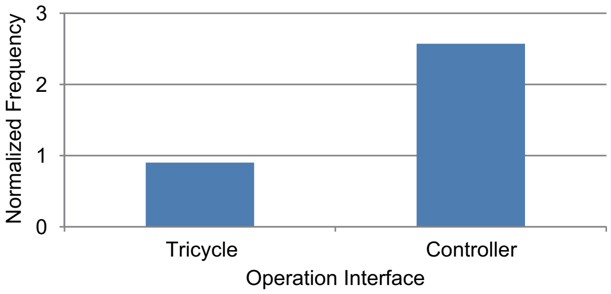

Figure 12: Average number of statements spoken by the bystander to the operator in each session. The difference between the two means is not statistically significant.

7 Conclusions

The study presents a tricycle-style operation interface designed for children to intuitively control a remote telepresence robot. It also presents results from a field experiment designed to assess the usability of the interface and to highlight its advantages and disadvantages over a standard video-game controller.

The tricycle-style operation interface was shown to be more operable than the video-game controller and can assist communication between the operator and people in remote locations. However, for promoting communication between the operator and his/her colleagues in the same room, the concept of a shared display becomes important.

These observations suggest that equipping the tricycle-style operation interface with a large monitor screen, enabling other persons in the room to share the view, would be beneficial when enriching childhood education with the telepresence robot.

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