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# Encouraging prosocial behavior from older adults through robot teleoperation: A feasibility study

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**Introduction:** In Japan, the social climate surrounding older adults has gotten worse as a result of the spread of COVID-19 and the growing isolation of older adults who are increasingly unable to engage in prosocial behavior through work and volunteering. This is detrimental to the physical and mental well-being of older adults. The purpose of this study is to look into robot teleoperation for older adults as a viable way to deal with these issues and overcome the barriers preventing older adults from engaging in prosocial behavior.

**Materials and methods:** We designed and tested a remote-control approach for dialogue agents that is appropriate for older adults as well as evaluating their impressions in a real-world setting. Twelve older adults participated in experiments in two separate locations, a children's center and the city ward office, where they could remotely teleoperate a robot and have conversations with the visitors. In the city ward office, the older adults had a conversation with the visitors and gave them information and trivia quizzes about the city. In the children's center, older adults had conversations with children regarding their age, family, their likes, and dislikes. A questionnaire and interview were set up after the experiments to understand their impressions of the system and to clarify how older adults feel about certain issues regarding remote-controlled work, starting a new job, social interaction, to what extent have older adults been affected by the pandemic, how and in what ways has it affected their involvement in society, and whether teleoperating a robot can be a suitable approach to encourage prosocial behavior from them through volunteer work and social engagement.

**Results:** The results show that older adults have a strong desire to engage in volunteer work, but are hampered mainly by physical isolation resulting from COVID-19 restrictions and their declining physical and mental health. Their impressions of the teleoperation system were highly positive, as they enjoyed having conversations with children through the robot. With this teleoperation system, older adults were able to remote control a robot by themselves without major issues. It made interaction simpler as conversing with children through a robot added a layer of anonymity that allowed older adults to express themselves freely without worrying about how they are perceived by others in public.

**Discussion:** Older adults were able to successfully engage in prosocial behavior through remote-controlling a robot. The system seems to be effective at easing the physical barriers preventing older adults from engaging in volunteer work, which have worsened since the spread of COVID-19.

## KEYWORDS

older adults, teleoperation, prosocial behavior, remote control, interactive agent

## 1. Introduction

As of 2020, in particular, the social environment surrounding older adults has deteriorated due to the spread of COVID-19 as more and more adults become more isolated (Sayin Kasar and Karaman, 2021), given that many older adults live alone or only with their partners (United Nations, 2017). Other factors such as physical isolation, lack

of transportation, and health declines can limit the older adults' ability to travel and commute and thus can amplify their isolation (Cotton et al., 2012; Winstead et al., 2013). This isolation is also dangerous for older adults as isolation and loneliness have been shown to be heavily linked with the onset of dementia (Holwerda et al., 2012). Additionally, isolation also limits their involvement in prosocial behavior through volunteer work and engagement with their community, which is essential for their wellbeing.

Prosocial behavior, which includes offering support, cooperation, consolation, sharing, volunteering, and making donations (Greener and Crick, 1999; Eisenberg et al., 2007), is described as an activity that benefits others (Eisenberg et al., 2015). For the "helper," this behavior can have a variety of positive benefits, such as mood-boosting effects, where the helper is more likely to feel good after helping and experiences bad mood less frequently overall (Raposa et al., 2016). Research has demonstrated that social support can have a favorable impact on wellness, including lowering the likelihood of loneliness, alcohol use, and depression (American Psychological Association, 2019). Another advantage is the ability to reduce stress. Prosocial activity can help lessen the negative emotional impacts of stress, and helping others can be a fantastic way to lessen stress in one's own life (Raposa et al., 2016).

We can therefore see that prosocial behavior is crucial for older adults for fostering social integration and maintaining healthy social interactions. Social relationships are extremely helpful, as keeping the mind active through conversation helps in limiting the onset of dementia (Fratiglioni et al., 2000) and has also been shown to reduce loneliness (Perese and Wolf, 2005). The benefits of playing a productive role in society to one's physical and mental health have been thoroughly proven (Luoh and Herzog, 2002; Musick and Wilson, 2003). Older adults may experience social retreat and a loss of identity and purpose after retirement, which can be harmful to their physical, psychological, and social wellbeing (Moen et al., 2000). After retirement, engaging in productive activities, whether paid or unpaid, has been demonstrated to protect against these consequences (Luoh and Herzog, 2002), with stronger benefits in volunteer work by older persons (Li and Ferraro, 2006). Volunteer work in the form of intergenerational programs has been introduced by local Japanese governments where older adults support children in local schools in an effort to fight social isolation (Murayama et al., 2015). Intergenerational programs have been shown in prior research to positively impact a number of outcomes. Improved physical and mental health, as well as more social interaction, benefit older persons (Hong and Morrow-Howell, 2010; Murayama et al., 2015; Sakurai et al., 2016). These programs will help students' academic achievement, attitudes toward volunteering in the community, and perceptions of the elderly (Murayama et al., 2012; Yasunaga et al., 2016).

## 2. Related work

According to the studies done by Cotton et al. (2012) and Winstead et al. (2013), older adults can use communication technology to overcome social and spatial limitations. Winstead et al. (2013) describe qualitative studies in which older adults in assisted living communities used technology such as Google Maps with Street View and virtual tours of cultural institutions to stay connected to places of sentimental value or to "visit" places of

interest that were no longer accessible to them. Loneliness and social isolation were reduced as a result of these internet visits.

The current spread of coronavirus is expected to subside with the roll-out of vaccination, but new variants are constantly appearing and new viruses may emerge in the future. On the other hand, remote work has grown rapidly during the coronavirus pandemic (Brynjolfsson et al., 2020), however, there is speculation about whether older adults can cope with this change and whether they can participate in society remotely. Kostoska et al. (2015) wanted to answer this question of whether older adults can participate in society by virtual participation of a museum visit, where they found that older adults were able to understand the presented museum content and were perfectly able to follow the virtual tour.

But joining online museum tours might not be enough, as older adults might be more inclined to take an active role in their community. It is expected that older adults are highly motivated to engage in society but within some temporal and spatial limitations. For example, a majority of older adults want to work (paid or non-paid) but in fairly short intervals of time and at a location that is close to their homes (Ministry of Health Labor and Welfare, 2015). Another limitation is that many of them want to perform tasks that are similar to what they did before they retired or use their existing knowledge and experience (Ministry of Health Labor and Welfare, 2015). However, these limitations, coupled with their physical isolation, make it very difficult for older adults to find such work. Ibarra et al. (2016) reviewed online tools (paid and non-paid) that enable social contributions by older adults. The tools included general-purpose volunteering services and crowd-sourcing services. They found that very few remote online contribution sites specifically target the adult population with very low support. They found that older adults want to help others by making a difference in causes they care about where helping others is the motivating factor; however, few of their reviewed online tools are expressly developed for older adults, both in terms of technology and online work.

Therefore, it seems that older adults are motivated to perform prosocial behavior through volunteering within limitations and there are very few options targeted specifically for older adults. One possible solution to this problem is through performing tasks by teleoperation of a robot. By operating a robot from a remote location, we can solve problems regarding time and distance. Short and long distances between work locations would not be an obstacle anymore, also making it possible for older adults to work only for short periods of time.

Teleoperation, in general, means performing some kind of work from a distance, although "work" can be almost anything. Teleoperation is a robot technology in which a human operator (master) commands a robot from a distance (slave). The teleoperator, a slave robot at a remote site, and the control module make up the system. Teleoperation has traditionally been utilized in instances where typical on-board manual operation/control is not possible or would be too dangerous or costly. Handling nuclear materials (dangerous), controlling small models (difficult), and space and undersea exploration (too hazardous and expensive) are all examples.

Modern teleoperation started when the first master-slave manipulator for chemical and nuclear material handling was created in the Argonne National Laboratory toward the end

of the 1940s (Goertz, 1949). Following it, the advancement of teleoperation was rapid. The earliest telepresence systems were made possible by adapting visual technology and force feedback to teleoperation. Computer technology enabled elaborate control loops to be implemented at the remote (teleoperator) end of the system, and virtual reality was ultimately introduced to teleoperation (Taylor et al., 1993). Teleoperation has been utilized in so many fields as was previously mentioned, but we will only consider specifically Telepresence robots in the context of telepresence applications where the presence of a human is replaced with a robot that is remotely operated by another human.

A typical example of telepresence applications is teleconference such as the PEBBLES teleconferencing robot (Yeung and Fels, 2005) from Telbotics, which is a telepresence system that uses a remotely controlled robot to allow elementary school children who are unable to attend school due to illness or other reasons to establish a presence in their classroom. Other applications of telepresence robots include nursing and healthcare applications. This is especially important in Japan where the population is getting older, thus there is a bigger need for nurses and healthcare professionals. Teleoperated robots, in this case, can provide a way for patients to get in contact with a nurse. A nurse will be able to operate several robots and attend to multiple patients simultaneously.

In this study, we developed a prototype of a robot teleoperation system that can be easily operated by older adults and conducted experiments in a real environment to evaluate their impressions of the system, including whether older adults can accept it. A questionnaire and interview were set up to clarify how older adults feel about certain issues regarding remote-controlled work, starting a new job, and social interaction in general. We want to understand to what extent have older adults been affected by the pandemic, how and in what ways has it affected their involvement in society, and whether teleoperating a robot can be a suitable approach to encourage prosocial behavior from them through volunteer work and social engagement. We hypothesize that older adults want to have a sense of purpose and want to engage in prosocial behavior mainly through participating in society by volunteering in social work even though it has become more challenging due to physical, social, and health constraints. And if they do want to engage in such activities, can we provide them with the means to perform such activities that can overcome the previously mentioned barriers? In this paper, we report the initial results.

## 3. Materials and methods

### 3.1. Robot teleoperation

#### 3.1.1. Robot used

The robot used was a small interactive robot “RoBoHoN” manufactured by Sharp Corporation (Sharp Corporation, 2021). RoBoHoN is a small child-like robot with a height of 19.5 cm and a mass of about 360 g. The robot used is shown in Figure 1. RoBoHoN uses a Qualcomm Snapdragon 430 processor (8x ARM Cortex A53), 16 GB ROM/16 GB RAM. The robot includes a speaker, an 8-megapixel camera, a three-axis accelerometer, a three-axis magnetometer, a three-axis gyroscope, Bluetooth, Wi-Fi, and

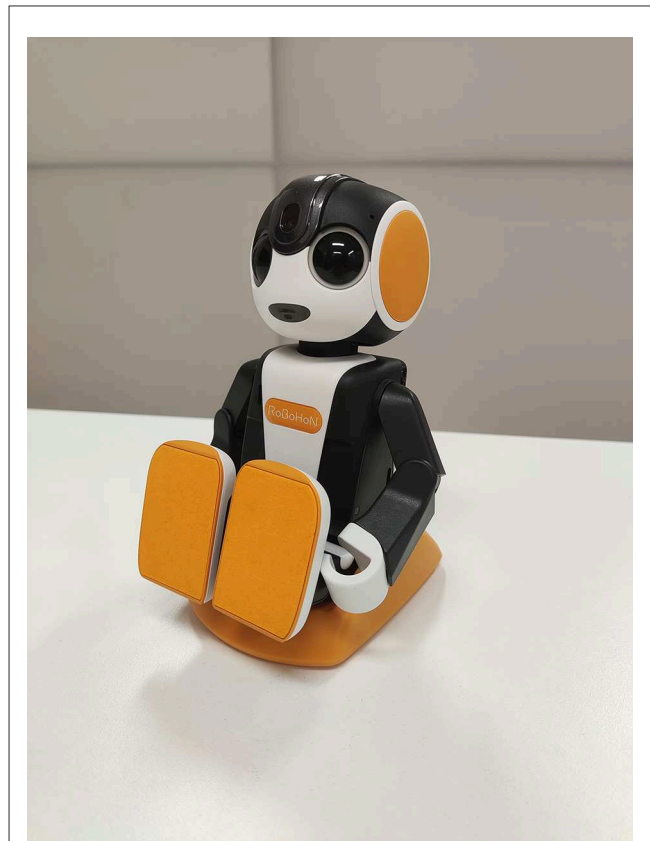


FIGURE 1  
The figure shows RoBoHoN by Sharp Corporation (2021).

GPS, as well as a microphone array with two microphones that allows for an approximate estimation of horizontal sound source direction. LED lights are also placed on its mouth and eyes. A touch screen is also mounted on the robot’s back. It also has built-in motors in its neck and arms and can perform gestures and speech synthesis. In this study, with the cooperation of Sharp Corporation, we modified the firmware to enable voice recording and servo motor control, and introduced an application for remote control, which will be described in the next subsection, and used for the experiments.

#### 3.1.2. Remote control

The teleoperation system was developed using WebRTC. On the operator side, we developed an interface that runs on a Web browser, and on the robot side, we developed an application using a native library and connected it using an existing signaling and TURN server. Media streams are used for video and audio transmission, and data streams are used for robot control and status acquisition.

The robot’s speech can be generated in four different ways:

1. Direct transmission of the operator’s voice.
2. Text-to-speech speech with text input.
3. Text-to-speech where specific pre-defined set phrases can be pressed on the screen.
4. Speech recognition and speech re-synthesis.

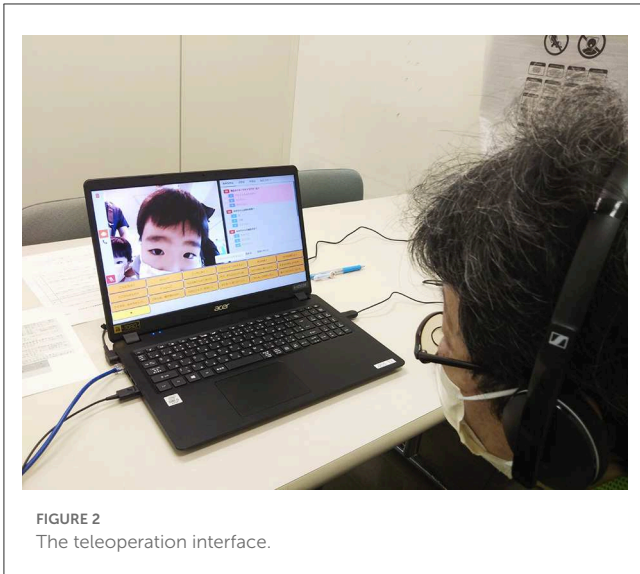


FIGURE 2  
The teleoperation interface.

For cases 2, 3, and 4, the same robotic voice is used regardless of the operator, as RoBoHoN's own built-in speech synthesis mechanism is used. For case 1, a voice changer can be used, but the voice output will be different for each operator as it is a direct transmission of the operator's voice.

Figure 2 shows an example of a remote control interface. The upper left corner of the screen shows the image captured by the robot's onboard camera. By looking at this screen, the operator can recognize that there is a person in front of the robot and can clearly see him. In this area, when you move the mouse over to the left, center, and right sides of the screen, buttons are displayed to rotate the robot's neck angle to  $-45^\circ$  (facing left),  $0^\circ$  (facing front), and  $45^\circ$  (facing right). The camera angle can be adjusted by clicking each button. When the mouse is moved over to the upper right corner, a button for disconnection appears, which can be clicked to end the remote control. On the left side of the screen, there is a button to cancel the speech, a button to switch between the robot's voice and the operator's voice by voice recognition, and a mute button. On the right side of the screen is an area where pre-determined speech content is placed according to the specifics of the experiment. In this experiment, we conducted a quiz and a guide to the facilities of the experiment location, so the text boxes were configured accordingly.

## 3.2. Experiment

### 3.2.1. Experimental procedure

Two separate experiments were conducted, each at a separate location, with the cooperation of Sakai City, Osaka Prefecture. A total of twelve older adults participated in the experiments. Five older adults participated in the first experiment which was at Sakai City Ward Office, and seven older adults participated in the second experiment which was at a large children's center. In both experiments, older adults interacted with the robot by remote control as shown in Figure 3. The experiments were conducted with the approval of the "Ethics Committee for Research Involving

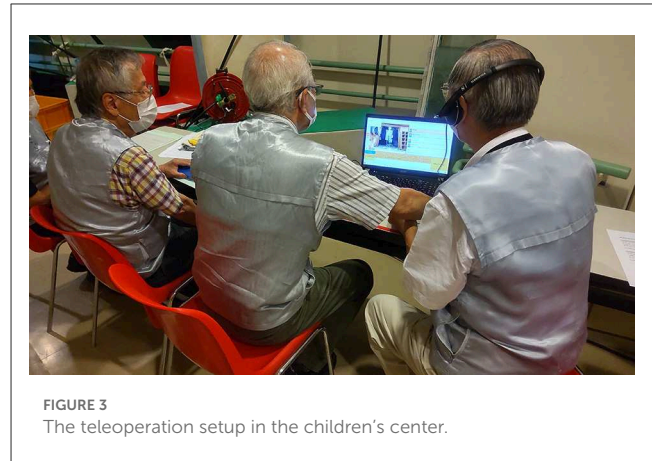


FIGURE 3  
The teleoperation setup in the children's center.

Human Subjects at the Graduate School of Engineering Science, Osaka University" (Approval No. R2-32-2). Written consent was obtained from the older adults who were to serve as the operators, and visitors to the facilities were given an explanation of the experiment, and consent was obtained by an opt-out method. The details of the experiment at each facility are described below.

In the experiment at the ward office, the robot was operated for a total of 1 h and 30 min per day over 3 days. Five older adults took turns operating the robot over the 3 days. The robot was set up on the first floor of the ward office, where pamphlets and other materials were placed. Two activities were included in this experiment, a conversation and a trivia quiz. These two activities were the same across the three days of the experiment. The robot was used to call out to visitors (e.g., by saying "Hello") to arouse their interest and encourage dialogue. When visitors came in front of the robot, the robot was remotely controlled by the older adults from a separate location in the facility. The visitors chatted with RoBoHoN and were given a quiz to teach them about their district. The older adults often asked visitors about their age, family, and what they liked and disliked, and they responded appropriately to visitors' responses and questions. In order to make it easier to hear the other person's voice and to make the robot's voice louder, a speaker with a microphone was placed near the robot and connected *via* Bluetooth. The quiz about the South District included questions in four categories with five questions in each category for a total of 20 questions. The categories were, "District mascot," "Sue Pottery," "District specialty produce," and "District famous spots." The quiz was mainly aimed at children although some of the visitors who participated were adults. When visitors give a wrong answer, the RoBoHoN operator would give them the right answer with more information. Some of the questions asked to visitors in the quiz:

- Who is the mascot of the South District?
  - a. Sakaeru & Misosakai
  - b. Mimi-chan

**Answer:** The correct answer is Mimi-chan.

*Information:* Mimi-chan, the mascot of South district, is the source of everyone's smiles!

- What is the name of the Kofun period earthenware produced in the South District?

- a. Sue pottery
- b. Haji pottery

**Answer:** The correct answer is Sue pottery.

*Information:* Sue pottery is characterized by being fired in a kiln, and it is said that it turns gray because the pores are sealed in the end!

- What is the characteristic color of Sue ware?

- a. Gray
- b. Reddish brown

**Answer:** The correct answer is Gray.

*Information:* Sue Pottery is the root of Arita pottery and Bizen pottery, famous Japanese pottery!

- What is the name of the produce stand at Harvest Hill?

- a. Matakitenā
- b. Asukate kuru De

**Answer:** The correct answer is Matakitenā.

*Information:* Sakai grown agricultural products “Sakai-no-megumi” are sold at “Matakitenā”

- What are the annual rice planting and harvesting events held in the South District?

- a. Nogyo juku
- b. Tanbo ni GO! Hata ni GO!

**Answer:** The correct answer is Tanbo ni GO! Hata ni GO!

*Information:* This year we changed to a stay home plan and implemented it!

- Which park is located in the South District, famous for its beautiful rows of meta sequoia trees?

- a. Shinhinoo Park
- b. Ohasu Park

**Answer:** The correct answer is Shinhinoo Park

*Information:* Shinhinoo Park is also a cherry blossom viewing spot with 900 cherry trees planted there!

The second experiment was conducted at the children’s center for 2 days. On the first day, the robot was set up in a corridor on the second floor of the facility, and two older adults took turns operating the robot for a total of 1 h and 30 min (with a break of 30 min for every 30 min). On the second day, the robot was set up in the exhibition room on the fourth floor of the facility, and the robot was operated for a total of 3 h. In the morning, it was operated by two older adults for 1 h and 30 min (with a 15 min break for each 30 min period). In the afternoon, it was operated by three older adults taking turns for another hour and 30 min. Since it was a children’s center and during the long vacations, there were many visitors, so we did not make any special calls to visitors. In this experiment, a conversation was the only activity included. The older adults had a conversation with the children regarding their age, family, their likes and dislikes, and why they came to the facility.

### 3.2.2. Questionnaire and interview

A questionnaire and an interview were conducted with each operator after the experiment. The items in the questionnaire were asked again in the interview to allow the participants to elaborate more on their answers. Therefore, the questions in the interview include the items in the questionnaire and items specific to the interview.

The items of the questionnaire and interview are written in bold below, while the intent of the questions is shown right below it. It will be specified next to the item in parentheses whether the question was asked in the interview only or both the interview and the questionnaire.

**Q1—Do you currently have a job? (interview)**

**Q2—Do you want to work? (interview)**

With these questions, We wish to investigate the demand for remote-controlled robot work to see if there were any older adults who wanted to work, and in what conditions and restrictions would they be interested in working.

**Q3—Do you have any concerns regarding COVID-19? (interview)**

**Q4—Has COVID-19 changed your lifestyle? (interview)**

With these questions, We wish to understand how older adults have been affected by COVID-19 and whether this has created a barrier to their engagement in society. This also helps us verify the need for remote control work as a result of social circumstances.

**Q5—Do you get any opportunities to interact with children?(interview and questionnaire)**

**Q6—Do you like children? (interview and questionnaire)**

**Q7—Do you want to interact with children? (interview)**

**Q8—Do you have any concerns about interacting with children? (interview)**

With these questions, We wish to understand how older adults usually think about interacting with children and how they thought about them as a result of the experiment by interacting with children through a robot. The purpose is to verify whether interacting with children through a robot would ease communication difficulties between these two age groups.

**Q9—What are you worried about when you start a new job? (interview and questionnaire)**

**Q10—What do you feel you can no longer do as you get older? (interview)**

**Q11—Did you have any worries before participating in this volunteer project? (interview)**

With these questions, We wish to identify whether there are any barriers (health-related or otherwise) that might prevent older adults from working or volunteering.

**Q12—How did you feel when you operated the robot? (interview and questionnaire)**

**Q13—What is the best thing about interacting with a robot by remote control? (interview)**

**Q14—What was not good about the robot's remote control interaction? (interview)**

**Q15—Do you want to participate again? (interview and questionnaire)**

With these questions, We wish to understand how older adults felt about interacting with the robot by remote control, the positives and the negatives, in addition to their general impression of the system and their experience with it.

**Q16—Please tell us about any difficulties you had with the controls or shortcomings you had with the robot. (interview and questionnaire)**

**Q17—Are there any parts that you find difficult to operate? (interview and questionnaire)**

In order to create an interface that is easy to operate for older adults who are not proficient in operating the system; with these questions we wish to identify necessary improvements to the interface.

### 3.2.3. Participants

In total, 12 older adults participated in the two experiments. There were no dropouts. Seven participants were male and five participants were female. The average age of the participants was 74 years old (We only obtained age data for seven of the participants). Given that both experiments were conducted in Sakai city, ten of the participants actually did reside in Sakai city. One participant lived in Osaka city, and another participant lived in Sayama city, which are both close to Sakai city.

For the experiment in the Sakai City ward office, the recruitment process happened through mediation, where the staff of the ward office contacted the president of the residents' association in the southern district. The president then worked on recruiting participants for the experiment. For the experiment in the children's center, the staff of the Sakai City ward office contacted the director of the children's center, and the director recruited participants from the facility's registered volunteers.

All participants had no previous experience with a robot. When we inquired about their experience with smartphones, ten participants claimed to use smartphones on a daily basis while two participants said they only use smartphones sometimes. Regarding their experiences with computers, six participants said they use a computer on a daily basis, while four participants use a computer sometimes, and only two participants stated that they rarely use a computer.

## 4. Results

The results of the questionnaires and interviews of the 12 older adults are summarized below. The items of the

questionnaire and interview are written in bold below, while the summary of the answers of the participants is shown right below it.

**Q1—Do you currently have a job?**

Eleven participants stated that they do not currently hold a job, although two of them said that they do volunteer work. Only one participant stated that he currently work.

**Q2—Do you want to work?**

Two participants stated that they have no interest in working at all, While the rest of the participants showed an interest in working as volunteers. The predominant mindset of most of the participants seemed to be an aversion to full-time (9 to 5) kind of jobs and more of an inclination to a less time restraining form of volunteer work where they can serve the community. One participant said, "As long as I am healthy, I would like to work to help others." In addition to just volunteer work, some participants wanted to work in a way that utilizes their hobbies and interests.

**Q3—Do you have any concerns regarding COVID-19?**

Seven participants said they do have concerns regarding COVID-19, while five participants stated they do not have any concerns. The participants who said they have no concerns explained that the reason for that is they have been heavily taking precautions.

**Q4—Has COVID-19 changed your lifestyle?**

All 12 participants stated that their lifestyle has changed because of COVID-19. The predominant answers are mainly a reluctance to leave the house, avoiding public transportation, only going out for groceries or emergencies, and basically cutting out outdoor activities and hobbies.

**Q5—Do you get any opportunities to interact with children?**

Two participants said they hardly ever get any opportunities, while ten participants said that they do get regular opportunities to interact with children through their volunteer work, or children in their family or neighborhood.

**Q6—Do you like children?**

Nine participants said that they like children, while three participants said they are not sure, thus seemingly reluctant to say that they are not that enthusiastic about children.

**Q7—Do you want to interact with children?**

All participants said that they do want to interact with children, however, two of the participants didn't seem particularly enthusiastic and said that it ultimately depends on how the interaction might be.

**Q8—Do you have any concerns about interacting with children?**

Eight participants said that they have no concerns about interacting with children while four participants stated that they have some concerns depending on the child's age and personality. They were quite worried about how noisy and active children might be, or that the child might run off to some strange place and that might be too much for them to handle.

**Q9—What are you worried about when you start a new job?**

Two participants mentioned that they have no concerns when starting a new job, while eight participants had concerns summarized as follows:

- Anxiety about starting new things.
- Jobs that require more knowledge than what they already have.
- Jobs where they have to assume responsibility.
- Tasks that make them feel insecure.
- Their deteriorating memory because of their age.
- Whether they can keep up because of their age.
- Whether they can keep up with the changing societal structure and technology.
- Whether others can accept the way they think.

**Q10—What do you feel you can no longer do as you get older?**

One participant said that they can't think of anything in particular that they can no longer do because of their age. The answers of the other nine participants are summarized as follows:

- A decline in physical fitness.
- Deterioration of their eyesight.
- A decline in motor skills.
- A decline in memory.
- A decline in concentration.
- A decline in strength.
- A decline in muscle power.
- They get easily bored when doing something.

**Q11—Did you have any worries before participating in this volunteer project?**

Nine participants said that they were not particularly worried, the others said they had some worries but they thought they could do the task if it was properly explained to them and if it was something new and interesting. Two participants were worried, though their worries were mainly about causing fatal damage to the computer by mishandling it.

**Q12—How did you feel when you operated the robot?**

Seven participants said that operating the robot was fun, four participants said that it was interesting, while one participant

said they felt nothing in particular. Most participants who found it fun mentioned that they mostly enjoyed talking to another human through a robot and specifically being able to speak with the robot's voice instead of their own, one participant even said, "it felt as if I was transformed."

**Q13—What is the best thing about interacting with a robot by remote control?**

The answers of all participants are summarized as follows:

- The fact that the other person was interested in the robot and could talk to it.
- The fact that I could talk to a child for the first time in a while.
- The fact that I could talk in the robot's voice.
- The fact that I could talk to a child from the perspective and voice of a robot.
- The fact that the hurdle of talking to a child is minimized.

**Q14—What was not good about the robot's remote control interaction?**

The answers of all participants are summarized as follows:

- It was difficult to speak as a "child" as per the robot's age setting.
- The other person cannot perceive the robot's emotions.
- It was somehow not good to interact in a non-face-to-face manner.
- It was difficult to understand the other person's voice and reactions.
- I cannot hear what I said so it was difficult to know if the robot actually repeated what I said.

**Q15—Do you want to participate again?**

One participant said "maybe" because it was too much trouble to leave the house. Eleven participants said that they would like to participate again as they enjoyed speaking through the robot, and they want to operate the robot in a better way next time and want to see improvements in the system. One of these 11 participants said that he is interested in participating again as it might help slow down the aging of his brain.

**Q16—Please tell us about any difficulties you had with the controls or shortcomings you had with the robot.**

The problems that the participants mentioned are as follows:

- The time lag caused by voice recognition makes the system difficult to use.
- Confusing button layout. It is difficult to locate the buttons.
- It would be better if the robot could move its head vertically.

**Q17—Are there any parts that you find difficult to operate?**

The problems that the participants mentioned are as follows:

- they were not able to understand what the robot was saying and the timing of the speech.
- they were not able to deal with problems by themselves.
- they were not used to using a mouse.
- there was a time lag due to communication speed or voice recognition.
- they were not used to using a computer.
- it was difficult to understand the position of the buttons.
- it was difficult to hear the other person's voice.

## 5. Discussion

From the results of **Q1** and **Q2** of the questionnaire, a majority of the people mentioned that they do not currently work and would like to work but as a volunteer. This shows their readiness to engage in prosocial behavior through volunteering as they are less interested in a full-time job. Their interest lies mainly in helping others and serving the community. This confirms our hypothesis that older adults do want to engage in society mainly through volunteer work but within short time periods (Ministry of Health Labor and Welfare, 2015).

We suspect that older adults want to engage in volunteer work but are limited by a number of factors such as the spread of COVID-19 and declines in physical and mental health. There might be other factors involved such as anxiety relating to starting a job or volunteering in something new that is far from their previous area of expertise and knowledge.

From **Q3** and **Q4**, all participants mentioned that their lifestyles changed due to COVID-19 and seven of them mentioned that they do have concerns regarding the pandemic. Most participants are interested in engaging in volunteer work but are physically unable to due to their changed lifestyles as a result of the spread of the coronavirus. This shows that there is a need for participating in society remotely and it confirms the limitation that older adults are interested in engaging in society but are restricted by spatial limitations (Ministry of Health Labor and Welfare, 2015).

With **Q9** we were trying to identify what factors might be causing concern or anxiety for older adults when beginning a new job (or volunteer work). This might be helpful in better designing our system to overcome some of their concerns. From the participants' responses, older adults seem to be rather anxious about engaging in activities that they are not used to doing. They feel the decline in their physical and mental abilities as well as their lack of knowledge of the new activity is a limiting factor. Having a system that can support their work is therefore essential in overcoming such barriers. In the first experiment at the ward office, the quiz that was conducted by older adults was provided as text boxes on the side of the screen. This is helpful in overcoming obstacles related to their deteriorating memory, age, and lack of knowledge in certain areas.

From **Q10**, we were trying to understand how older adults feel they have been physically and mentally affected as they get older.

Their responses varied from a decline in physical abilities (physical fitness, eyesight, motor skills, strength) to a decline in mental abilities (memory, concentration). The decline in their physical abilities is a great hindrance to their ability to commute and be physically present to engage in volunteer work, and the decline in mental abilities is also a hindrance to the type of volunteer work they are able to engage in. Using a robot teleoperation system, we hope it helps to overcome the physical factors (by teleoperating from a distance) and mental factors (by giving on screen support and knowledge) preventing older adults from engaging in volunteer work.

As for the remote control, from **Q11** most participants stated that they were not initially worried and thought they can do it if the process is properly explained to them and that it seemed like something new and interesting even if it was difficult. Two participants stated that they were actually worried but thought they could manage as their biggest concern was causing damage to the equipment. This suggests that even though older adults might show slight concerns, they are not averse to trying something new if it is well explained to them and the system was easy to use to some extent.

### 5.1. Encouraging prosocial behavior

In the experiments at the ward office and the children's center, older adults engaged in prosocial behavior by interacting with children. From **Q5**, **Q6**, **Q7**, and **Q8**, most participants were looking forward to engaging with children. The older adults wanted to help children in the ward office by introducing and explaining to them the district's famous sites, products, and historical artifacts. In the experiments at the children's center, they wanted to help children by providing them entertainment and giving them advice, and even helping their parents. One of the older adults stated the following, "With young children, I think it is worthwhile to help them in various ways and teach them various things." Another older adult said, "I love seeing children have fun, and I also want to help their parents raise their children a little." The older adults received satisfaction from these interactions mainly through feeling the enjoyment of the children and their interest in the robot, or even just through the opportunity of talking to a child. Just as was shown by Raposa et al. (2016), the "helper" engaged in prosocial behavior will experience positive benefits such as feeling good after helping. One of the older adults said, "It was great to feel the children's interest in the robot, and their various reactions to what I said." The participant here felt joy purely through observing the children's reactions to the robot. The use of a robot here as a medium has eased communication between two different groups of people that might usually have a hard time communicating. As children found communicating with a robot fairly interesting and enjoyable, older adults were glad to be the cause of that joy. Another older adult said, "I don't have any grandchildren, but I think that children, no matter who they are, are very dear to me. That's why in this experiment, I felt glad to talk to a child for the first time in a long time." The older adult here has been lacking the opportunity to talk to children due to physical isolation even though he much enjoys it.



By teleoperating a robot, he can overcome that obstacle and engage with children remotely.

In the experiment at the ward office, from the point of view of the “receiver,” the children and adult visitors were able to get helpful information and gain knowledge about their city and received guidance on some important historical sites and social events. The other “receiver” is the ward office, which might see an increased number of visitors that would like to interact with the robot, and reduce the workload of the staff that can handle other inquiries from the visitors. In the experiment at the children’s center, the “receiver,” the children and their parents, visited the center to spend an entertaining day as a family. The children and parents seemed to gain benefit from their interaction with RoBoHoN by being able to experience new technology and by having an enjoyable conversational experience with a robot. Another “receiver” is the children’s center which can offer visitors the opportunity to interact with a robot, which might increase its number of visitors because of the availability of such a unique experience for families.

Therefore, older adults were able to successfully engage in prosocial behavior by participating in society through volunteer work. By teleoperating a robot, they were able to overcome spatial and temporal barriers that might otherwise prevent them from engaging in such behavior.

## 5.2. System impressions

Participants, in general, had favorable impressions of the teleoperation. From **Q15** when asked if they would like to participate in the experiment again, 11 participants answered that they would like to participate. Older adults seemed to enjoy engaging with other people through the teleoperation of a robot. From **Q12** and **Q13**, the positives of teleoperation with a robot were mainly making interaction much easier by pretending to be a robot like a masked effect due to the operator’s anonymity with respect to the target. Thus, the hurdle of talking to a child was lowered according to the participants. From **Q8**, some older adults had some concerns about interacting with children mainly due to their inability to control a child’s behavior, the older adult’s engagement through remote teleoperation makes it simpler to engage with children as it limits their involvement to only dialogue rather than worrying about how the child might behave in their presence. This also eliminated the embarrassment that some participants might feel when talking to a child in public as they can be self-conscious about how they might be perceived by others around them. Additionally, children might be more interested in speaking to a robot than speaking to an older adult face-to-face. This eases communication between older adults who are very interested in conversing with children and children who might be more interested in conversing with a robot.

The participants also stated they liked that they could talk through the robot from the perspective and voice of a child robot. One of the older adults stated, “I felt as if I was transformed, and I could experience the feeling of being in contact with the children.” This effect is termed the Proteus effect (Yee and Bailenson, 2007), where an operator conforms to the behavior that they believe others

would expect of them. In other words, the operator (in this case, older adults) behave as a child robot as they believe that this is the behavior that the perceiver (in this case, children) is expecting from the child robot. On the other hand, this also might have been an effect of behavioral confirmation (Snyder et al., 1977), whereby the expectations of the perceiver cause the operator to behave in ways that confirm the perceiver’s expectations. In other words, the perceivers (in this case, children) are talking to a child robot fully expecting its behavior and conversational ability to be that of a child robot. This expectation causes the operator (in this case, older adults) who are in complete anonymity to act as a child-like robot (confirming the expectations of the perceiver). In this case, speaking like a child as they believe they are being perceived as a child-like robot as opposed to an adult. It is crucial to note here that the change in behavior from behavioral confirmation originates from the perceiver rather than the operator. It is thus, the perceiver’s behavior that causes the operator to change his behavior, unlike the Proteus effect, where the operator changes his behavior regardless of the perceiver’s behavior. In this experiment, the change in behavior of older adults to match that of a child-like robot might have been a combination of both the Proteus effect and behavioral confirmation.

Aside from these mentioned positives, there were some negative aspects pointed out by the participants. From **Q16** and **Q17**, four people stated that the time lag caused by voice recognition created difficulty in operation. When speaking using the robot’s speech recognition and re-synthesis, the operator’s voice input is converted into character strings using speech recognition, and then synthesized to audio with RoBoHoN’s built-in speech synthesis mechanism. This slow process caused a lag as opposed to the direct transmission of the operator’s voice which would not require any speech recognition or re-synthesis. When participants learned about the various functions available for speech, they opted for the former as they felt it would be weird and embarrassing to hear their own voice come out of the robot. The time lag caused by the voice recognition also created a difficulty in communication with children, as children are typically impatient and have a short attention span. With a longer interaction time, this can cause the children to get easily bored.

Participants also stated that they were not able to understand what the robot was saying and could not perceive the timing of their speech. The reason for this was the use of a Bluetooth speaker and microphone for RoBoHoN’s speech. This speaker has a higher volume output and a better microphone sensitivity compared to RoBoHoN’s onboard hardware. The idea was to make it easier for visitors to hear RoBoHoN’s speech and to more clearly hear the visitors. However, the microphone speaker has an echo cancellation function that prevented the operator from hearing the audio output from the RoBoHoN. With these experiment conditions, it was very difficult for the operators to hear what they spoke, and were unable to understand the timing of their own speech. Therefore in the second experiment, the Bluetooth microphone speaker was removed and the standard RoBoHoN microphone and speaker were used. With these changes, some visitors commented that it was difficult to hear the robot’s voice. RoBoHoN’s built-in microphone is sufficient for autonomous conversation, as it is only required to recognize a certain number of keywords in speech, however,

its performance is not good enough to be used as a device for dialogue. For this reason, a microphone device with high sensitivity and no echo-cancellation function would be preferential. From Q16 regarding the operator screen layout, one of the participants mentioned that it was difficult to locate the positions of the various buttons for operation. Therefore, it is important to consider the size of the text, layout, and placement of the buttons to make it fairly simple to navigate even for unskilled users.

### 5.3. Limitations

It is important here to mention the limitations of this study. The people participating in this experiment are not randomly sampled. All the participants who joined this experiment showed an interest and curiosity in this project and were enthusiastic about trying it out.

## 6. Conclusion

In summary, older adults want to participate in society and would love to engage in prosocial behavior as they showed complete readiness in working as volunteers just as we hypothesized; however, there are several obstructions preventing them from doing so. We set out to explore whether the teleoperation of a robot was a suitable way for older adults to participate in society and we have found that it was generally effective. Older adults positively received the teleoperation experiment and were able to engage in volunteer work with very little difficulty. It was also very effective in easing communications as a layer of anonymity between the operators and visitors is added. Therefore the first two of the following steps have been achieved in this work:

- Verify whether older adults have a desire to engage in prosocial behavior, and what factors are obstructing them.
- Provide the means for older adults to overcome the barriers preventing them from engaging in prosocial behavior.
- Improve and reinforce people's desire to engage in prosocial behavior.

The third step, which will be a part of our future work, is increasing the desire to engage in prosocial behavior for people in general and not just older adults. For our future work, some improvements need to be implemented for the system, such as fixing the time lag issues caused by RoBoHoN's speech synthesis mechanism, and making the teleoperation interface easier with a better layout and font that can make navigation simpler for older adults. In addition to improvements in system design, we also want to test the system in different locations and for different purposes such as placing RoBoHoNs at tourist sites, where older adults operating the robot can give information to visitors and can act as their tour guides. We would also like to improve support for operators of the system by helping them maintain interesting conversations. The system would provide topic points to efficiently steer the conversation while keeping the visitors interested and engaged in the conversation. As talking to strangers might be

stressful and intimidating, this might help the operators to be more comfortable by helping them steer the conversation and create a more fun environment for the visitor. This can also be helpful in scenarios where the RoBoHoN is placed in touristic spots, the system can give the operator information regarding the spots and artifacts available in that location, thus allowing them to volunteer as tour guides even when they don't possess the required knowledge.

## Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

## Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee for Research Involving Human Subjects at the Graduate School of Engineering Science, Osaka University. The participants provided their written informed consent to participate in this study.

## Author contributions

EM: investigation, analysis, and writing—original draft. TH: investigation and analysis. RY: conceptualization, methodology, and writing—review and editing. SN: conceptualization, methodology, software, and writing—review and editing. HI: funding acquisition. All authors contributed to the article and approved the submitted version.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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