1. INTRODUCTION

Human symbiosis robots are extensively researched and developed nowadays. Especially, robots that help a user’s daily life are expected to become a solution to various problems arising in an aging society. When designing such robots, a designer should take safety into maximal consideration. In addition, the familiarity of the robots, such as usability or friendliness, has to be taken into account, too [1]. A straightforward way of improving robot familiarity with a robot, the effect of users’ age on the improvement of familiarity by a robot avatar was not investigated well because the most of the subjects in the previous study were young. When considering the application of a robot avatar to care service robots, it is important to investigate the effect of a robot avatar on elderly people. In this paper, we focus on elderly subjects, and carried out an experiment to test if a robot avatar is effective for elderly people to improve familiarity. The result was positive, and the effect of a robot avatar on elderly people was stronger than that on younger people. From a comparison of the results from elderly subjects with those from younger subjects, we found that the elderly paid less attention to dialogue between a human and a robot.

Abstract: Familiarity is one of the most important requirements for human symbiosis robots, such as care service robots. To improve familiarity of a human symbiosis robot, we proposed a novel concept called “robot avatar.” A robot avatar is a small robot mounted on a main robot, and it performs gestures instead of the main robot. Although our previous study revealed that a robot avatar was effective for increasing users’ familiarity with a robot, the effect of users’ age on the improvement of familiarity by a robot avatar was not investigated well because the most of the subjects in the previous study were young. When considering the application of a robot avatar to care service robots, it is important to investigate the effect of a robot avatar on elderly people. In this paper, we focus on elderly subjects, and carried out an experiment to test if a robot avatar is effective for elderly people to improve familiarity. The result was positive, and the effect of a robot avatar on elderly people was stronger than that on younger people. From a comparison of the results from elderly subjects with those from younger subjects, we found that the elderly paid less attention to dialogue between a human and a robot.

Keywords: Robot Avatar, Familiarity, Care Service Robot, Avatar, Elderly People

EVALUATION OF ROBOT-AVATAR-BASED USER-FAMILIARITY IMPROVEMENT FOR ELDERLY PEOPLE

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Abstract: Familiarity is one of the most important requirements for human symbiosis robots, such as care service robots. To improve familiarity of a human symbiosis robot, we proposed a novel concept called “robot avatar.” A robot avatar is a small robot mounted on a main robot, and it performs gestures instead of the main robot. Although our previous study revealed that a robot avatar was effective for increasing users’ familiarity with a robot, the effect of users’ age on the improvement of familiarity by a robot avatar was not investigated well because the most of the subjects in the previous study were young. When considering the application of a robot avatar to care service robots, it is important to investigate the effect of a robot avatar on elderly people. In this paper, we focus on elderly subjects, and carried out an experiment to test if a robot avatar is effective for elderly people to improve familiarity. The result was positive, and the effect of a robot avatar on elderly people was stronger than that on younger people. From a comparison of the results from elderly subjects with those from younger subjects, we found that the elderly paid less attention to dialogue between a human and a robot.

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There are a couple of related works that focus on human-robot interaction for elderly people. Wada et al. investigated human-robot interaction in the health care service for the aged using a seal-shaped robot [15]. Their work is instructive because they target elderly people. However, their robot was not a humanoid and it did not perform verbal communication. Yamamoto et al. used a small robot ApriAlpha and investigated the relationship between the familiar behaviors of a robot and the user’s tolerance to misrecognition of speech [16]. They compared younger and older subjects, and they found that the familiar behavior was more effective to elderly subjects than younger. Raux et al. constructed a spoken dialogue system for non-native and elderly users [17]. They improved the synthesized speech for improving comprehension of the system’s voice for those people. However, we have found no research that studies the effect of age on robot familiarity in a dialogue situation.

The object of this paper is to prove that a robot avatar is effective to elderly people. We compare elderly and younger people and investigate the difference of familiarity to a robot as well as how younger and elderly people focus on the appearance and behavior of a robot. To this end, we carried out the same experiment as described in [14] using elderly subjects.

2. OVERVIEW OF ROBOT AVATAR

2.1 Robot Familiarity and familiarity of IRIS

The Research Committee on Human-Friendly Robots defined four aspects of familiarity: physical familiarity, informational familiarity, emotional familiarity, and environmental and economic familiarity [1]. These familiarities can be viewed as functions that a human symbiosis robot should have. On the other hand, it is also important to consider familiarity from a human side, such as “looks friendly” or “less threatening.” A human symbiosis robot is required to have both functional familiarity and familiarity from human side, considering its robot design. Here “robot design” means not only the robot’s appearance but also its behavior in a situation.

Figure 1 shows our care service robot IRIS [13]. When designing IRIS, we considered those familiarities which dealt with the functions of a robot, described below.

- Physical familiarity: Considering physical contact with humans, we employed safety manipulators [18] that enable safer work around humans. We wrapped the arms with shock-absorbing material to reduce any force that might injure humans [19]. Its shoulders were equipped with clutches, which slip when more than a certain amount of torque is applied in order to maintain safety. The arms were designed to be light-weight by using a wire driving mechanism. As a result, the arms had less inertia, which reduces impact against humans.
- Informational familiarity: we designed the robot so that novice users who first use IRIS can control the robot at will. We designed a natural approach for the user by combining the recognition of a calling voice’s direction [20] with face detection [21]. We designed IRIS to perform spoken dialogues to understand the given task [20].
- Emotional familiarity: To express the robot’s emotion (internal state), IRIS was designed to utter words that express its current and future behavior (state), such as “I’m coming.”
- Environmental and economical familiarity: IRIS was designed to have the minimum function required in a real world nursing care service. Performance of each of these functions is improved step-by-step. Its dimensions are 500×450×1100 (WDH), and it was designed with consideration for the environment where IRIS was used.

However, there still remain the problems pointed out in the last section. From a robot design point of view, it is very difficult for one robot to have both high familiarity and high functionality, realizing both communication functions and working functions under the current robot technology.

2.2 A Robot Avatar

As discussed above, it is difficult to improve familiarity in a service robot that works in a real environment by changing its design. The difficult point is to realize both functionality and familiarity in one robot. Therefore, we
proposed a method of using two robots, a bigger robot that works in a real environment and a smaller robot that is mounted on the bigger one for communication purposes. The bigger robot has only physical and environmental familiarity, while the smaller one has informational and emotional familiarity. We call the smaller robot “a robot avatar.” [14]

A robot avatar is an avatar of a working robot, which means that it is the robot avatar that undertakes the communication role instead of the bigger robot.

The idea is neither to improve the performance of the working robot nor that of the robot avatar. The idea is that we make one robot system by combining both the working robot and the robot avatar. The novel point of this idea is to improve the familiarity of the whole robot system by adding the robot avatar to the working robot [14].

The familiarity of the robots can be improved by the design of the robot avatar, including its appearance and behavior.

2.3 Implementation of A Robot Avatar

We implemented a robot avatar on IRIS to solve the above-mentioned problems. The robot avatar is mounted on one of IRIS’s shoulders, and it performs gestures for improving familiarity according to IRIS’s situation. We call the robot avatar “CHIRIS.” [14]

Figure 2 (a) shows the appearance of CHIRIS. CHIRIS has a humanoid shape without legs. Figure 2(b) shows a degree-of-freedom diagram. CHIRIS has 1 DOF at the left and right arms respectively, 1 DOF at the neck, and 1 DOF at the bottom of the body, enabling CHIRIS to change its direction by rotating its body horizontally. CHIRIS can perform several kinds of simple gestures.

We already implemented CHIRIS, and found that CHIRIS can improve familiarity in the dialogue situation by performing the nodding gesture.

3. EVALUATION OF IMPRESSION

3.1 Object and Overview of The Evaluation

In the previous work [14], we investigated the effect of CHIRIS’s existence upon familiarity. In that study, we considered a scene in which IRIS reacted to the user’s calling voice at about 3m distance from the user, moved to the position where the robot can dialogue with the user, and then perform a dialogue. IRIS was at a standstill during the dialogue. We asked subjects answering an enquiry after presenting two video clips, where only IRIS appears in one clip, while IRIS with CHIRIS appears in the other one. As a result, it was found that many subjects focused on the dialogue process, even when IRIS was performing some actions. This result suggested that we could use only a dialog scene as a stimulus for subjective evaluation of familiarity improvement by a robot avatar. Then we confirmed that a robot avatar did improve familiarity using a video clip of a dialog scene. The procedure of the experiment was same as the experiment shown in 3.2.

In this paper, we focus on user familiarity in a dialogue scene just like the previous work [14], and we conduct the same experiment as the previous work [14] using elderly subjects. In [14], we used younger subjects. The purpose of the experiment is to investigate whether the method based on a robot avatar proposed in the previous work is effective for elderly people or not. Then we analyze the difference of elderly people’s familiarity to a robot compared with that by younger people.

As stimuli of the experiment, we presented two video clips to the subjects. One video clip was taken by a digital video camera, which contained a scene where only IRIS dialogued with a user. The other clip contained a scene where IRIS with CHIRIS did the same dialogue. We used the video clips instead of actual subject experiences because we want to keep the conditions of the experiment constant except for the existence of a robot avatar. The experimental paradigm using video clips can give the all subjects the same experience, although the problem is that the user does not actually control IRIS. For example, we can exclude the possibility that the performance of speech recognition affects the subject’s impression on the robot. Moreover, as we conducted an experiment using video clips on younger subjects in the previous work, we should conduct the same experiment using elderly subjects to compare the results of
the two experiments with each other.

3.2 Evaluation Procedure

We investigated the degree to which the subjects feel familiar with IRIS and with CHIRIS in a situation where a user dialogued with IRIS. In the video clip, a user asked IRIS to bring a PET bottle of tea (a tea serving task).

Figure 3 shows a flow diagram of the dialogue and actions of the user, IRIS and CHIRIS. An example of CHIRIS’s motions is shown in Figure 4. At the beginning of the dialogue, CHIRIS drops its head as shown in Figure 4(a), indicating that CHIRIS is not ready for dialogue. Next, as shown in Figure 4(b), CHIRIS raises its head indicating that it becomes ready for dialogue. Then it says, “How may I help you?” to prompt the user to start dialogue. The user says, “Give me a cup of tea.” CHIRIS confirms it by repeating the order with nodding gesture. The user says yes, and CHIRIS answers “all right,” nodding twice. The dialogue is done in Japanese.

The dialogue described above was recorded as a video clip. The subjects were presented two video clips. One clip had only IRIS doing dialogue with a user (the movie A), and the other had IRIS with CHIRIS, as shown in Figure 4 (the movie B). The subjects were asked to answer a questionnaire after watching the movie A and B twice. The questionnaire had two questions: question 1 was a multiple-choice question and question 2 was a free description, asking to describe the reason why the respondent chose the choice in question 1. The subjects had not seen the robots before the experiment. We gave the subjects no explanation of the ability of the robots.

The questions in the questionnaire were as follows:

Q1: How do you feel familiar with the robot in the video clips?
(a) I feel familiar with the robot in movie A.
(b) I feel familiar with the robot in movie B.
(c) I feel familiar with the robots in both movies. (Preference: movie A / movie B)
(d) I don’t feel familiar with the robot in either movie.

Q2: Please describe the reason for your choice.

The subjects were recruited from participants of the “Ishinomaki Senshu University Open Workshop,” which was held as a part of a lifelong learning program “Miyagi Kenmin Daigaku” in 30 June, 2005. Thirty-six volunteered (26 males and 10 females) as subjects, whose age ranged from 56 to 76 (mean age was 65.0).

3.3 Experimental Result of Improvement of Familiarity

First, we determined whether the subjects felt familiar to the robots using the chi-square test. We categorized those who chose (a), (b) and (c) in Q1 into “people who felt familiar,” and those who chose (d) into “people who didn’t feel familiar.” As shown in Table 1, all subjects felt familiar to the robot, which was significant at the 0.1% level. Next, we analyzed which movie was preferred by who felt familiar to the robot. The result is shown in Table 2. Those who felt familiar to the robot were those who chose the choices (a), (b) and (c). We asked a further question to those who chose (c) for asking which video clip did they prefer among A and B. As a result, no one chose the video clip A, whereas two people chose the video clip B. In total, 1 person felt more familiar with the video clip A, and 35 people chose the video clip B. From the result of the chi-square test, the movie B (IRIS with CHIRIS) was significantly preferred at the 0.1% level. This result proves that adding a robot avatar improves familiarity of elderly subjects to IRIS.

Next, we analyzed categories to which the subjects paid
Next, Table 5 shows differences of preference between younger and elderly people on familiarity to the robot. Table 6 shows preference of video clips by elderly and younger people.

As shown in Table 3, 26 people felt familiar to the robot and 3 people did not. This difference was significant at 0.1% level according to chi-square test. As shown in Table 4, 1 subject preferred the video clip A whereas 25 preferred the video clip B. From chi-square test, this difference was significant at a 0.1% level.

Next, we conducted chi-square test to investigate whether the difference of familiarity to the robot between younger and elderly people shown in Table 5. As a result, there was a significant difference at 5% level. Then we conducted the chi-square test on Table 6, and observed no significant difference. In summary, elderly people felt more familiar to the robot, which suggests that CHIRIS was more effective for elderly people than younger people.

Next, we analyze what part of the clips the elderly and younger subjects paid attention to. Figure 6 shows a comparison result of the categories of elderly and younger subjects' attention. From Figure 6, no significant difference was found for facial expression and motion. On the other hand, elderly subjects' attention to dialogue was about 15 points lower than the younger subjects' one. Instead, elderly subjects seemed to pay more attention to appearance. To investigate if this difference is statistically significant, we arranged the number of answers from the viewpoint of attention to dialogue, as shown in Table 7.

### Table 1: How elderly people feel familiar with the robot

<table>
<thead>
<tr>
<th>Feel familiar</th>
<th>Do not feel familiar</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>0</td>
</tr>
</tbody>
</table>

### Table 2: Elderly people's preference

<table>
<thead>
<tr>
<th>Movie A</th>
<th>Movie B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
</tr>
</tbody>
</table>

### Table 3: How younger people feel familiar with the robot

<table>
<thead>
<tr>
<th>Feel familiar</th>
<th>Do not feel familiar</th>
</tr>
</thead>
<tbody>
<tr>
<td>26</td>
<td>3</td>
</tr>
</tbody>
</table>

### Table 4: Younger people's preference

<table>
<thead>
<tr>
<th>Movie A</th>
<th>Movie B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25</td>
</tr>
</tbody>
</table>

### Table 5: Difference of familiarity with the robot between elderly and younger people

<table>
<thead>
<tr>
<th></th>
<th>Feel familiar</th>
<th>Do not feel familiar</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elderly</td>
<td>36</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>Younger</td>
<td>26</td>
<td>3</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>62</td>
<td>3</td>
<td>65</td>
</tr>
</tbody>
</table>

### Table 6: Difference of preference between elderly and younger people

<table>
<thead>
<tr>
<th></th>
<th>Movie A</th>
<th>Movie B</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elderly</td>
<td>1</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>Younger</td>
<td>1</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>60</td>
<td>62</td>
</tr>
</tbody>
</table>
We conducted Fisher’s exact probability test on Table 7, and found that the difference of attention to dialogue by elderly and younger subjects was significant at the 5% level.

We observed no significant difference about the appearance, motion and expression. Table 7 shows the results of the dialogue. These results suggest the tendency for elderly and younger people to pay different degrees of attention to the dialogue.

Here, we discuss the difference of attention on dialogue between elderly and younger subjects, comparing our result with previous work by Yamamoto et al. [16]. Yamamoto et al. reported that elderly people tended to permit the speech recognition errors of a mobile robot when the robot demonstrated familiar behaviors. Yamamoto did not describe the reason in the paper. One possible interpretation could be that elderly people pay less attention to dialogue. Under this interpretation, Yamamoto’s result seems to have a relationship to our result where elderly people paid less attention compared with younger people.

In our previous work [14], we carried out the same experiment as described in this paper using mainly younger subjects, and observed that familiarity was increased while attention to dialogue was decreased simultaneously when we added the nodding gesture to CHIRIS. In this paper, we observed a similar tendency for the two different subject groups, younger and elderly subjects, where elderly subjects had higher familiarity and lower attention to dialogue. This fact suggests that there might be some kind of relationship between familiarity to a robot and attention to the dialogue.

Only one subject among the elderly subjects described an answer concerning dialogue, which stated that the subject had a good impression of the dialogue and felt familiar to the robot. On the other hand, four subjects among the younger subjects gave an answer related to dialogue, one of them had a good impression of the dialogue, and answered that they did not feel familiar with the robot. It is interesting that this result corresponds to the observation that “those who have good impression of the dialogue tend to feel familiar with the robot, while those who have a bad impression of the dialogue tend to feel oppositely,” reported in the previous work.

4. CONCLUSION

In this paper, we evaluated a method to improve robot familiarity using a robot avatar, employing elderly subjects. From the experimental result, the following results were obtained.

• Elderly subjects feel familiar with a robot that has a robot avatar.
• Elderly subjects prefer a robot with a robot avatar to one without a robot avatar.
• Elderly subjects have a greater familiarity with a robot with a robot avatar than younger subjects.
• Elderly subjects pay less attention to dialogue than younger subjects.

From these results, we think that a method for improving familiarity using a robot avatar is effective not only for younger people but also elderly people. We should consider the design of a robot avatar, including its appearance and motion, based on the result obtained here. To investigate the effect of robot avatar design upon familiarity, we will compare robot avatars with a different design.

Furthermore, we will prove the effectiveness of the “previous notice of motion,” or “pointing gesture,” [22] for elderly people.

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