Fragile Robot: The Fragility of Robots Induces User Attachment to Robots

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***Abstract*—This paper describes a fragile robot and its psychological effects on humans. Nowadays, user support robots are starting to get into our lives. Many robots are designed to support the user's daily life as much as possible. However, such support can result in the user being forced to live a passive life. In contrast, some studies have reported the usefulness of robots that behave negatively to users. However, it may not be possible to maintain user attachment for a long period of time simply by repeating negative behaviors toward humans in the same way. In this study, we propose a concept of fragile robot and expect that the fragility of robots induces user attachment to robots. We conducted two experiments to check its validity and confirmed the appropriateness of our concept on an experimental basis.**

***Index Terms*—fragile robot, human-robot interaction, user attachment**

I. INTRODUCTION

Nowadays, robots are being found in various places in daily life. Educational robots [1], [2], cleaning robot [3], [4] and navigation robots [5], [6] are typical examples. These types of robots are generally designed to support users perfectly without making mistakes or errors.

However, in medical fields, it is known that one-way support from the caregiver to the care recipient is not always good. Such support sometimes has a negative impact on care recipients. For example, many older people often find life boring after reaching retirement age, with nothing to do. Studies have also shown that older people who do nothing have a very rapid physical and mental decline [7], [8].

Other studies report that people lose their self-esteem if they continue to be supported in their daily lives. They have a great deal of discomfort when forced to live passively [9]. The importance of work in daily life has been reported for people to have a purpose in life [10].

From the above perspective, some robot researchers report on robots that require human support. Some robots are designed to require human help to achieve human interaction. Unlike ordinary robots, such types of robots need collaborate with users to perform given tasks.

An example is a baby-like robot named Babyloid [11]. It was designed as a robot that can do nothing like a baby. The only features implemented in Babyloid were changing facial expressions and crying. The purpose of this study was to enhance user behavior towards Babyloid by taking advantage of Babyloid's features.

Yoshida et al. report on a trash type cleaning robot called Social Trash Box. [12]. Unlike common cleaning robots, the Social Trash Box cannot pick up trash. Instead of picking up trash, it moves closer to the user and waits for the user to pick up the trash. When the user picks up the trash for the robot, it bows and expresses gratitude. It cannot clean the room alone and cannot work without the help of the user.

They named this concept "the force of weakness" and showed that “The robot cannot do anything” enhances the user's involvement with the robot. These approaches are useful for strengthening the user's involvement with the robot. However, robots are passively waiting for user involvement.

We have developed a robot that sometimes makes mistakes in order to elicit more active user behavior [13]. The robot we developed is similar to the Social Trash Box. However, when the robot bows to thank users, it drops trash. By making mistakes, robots are creating new tasks that users have to do. They need to work again to help the robot. We conducted some experiments to check its validity. It was experimentally confirmed that the user had a favorable impression of the robot making the mistake.

However, many of these robots are passively waiting for help from users. We aim to elicit active user involvement by increasing the involvement of robots with users.

Following the success of the past approach, we have reported on several robots, including a rebellious robot [14] and a forgetful robot [15]. However, simply repeating negative behaviors against human will may result in short-term attachment. In this paper, we focused on fragile robots as characteristic that elicit attachment and familiarity from users without taking negative actions toward humans. Fragile robots cause the active human action of repairing each time they break. We expect that the robot breaks and the user repairs it, which will bring out the user's attachment to the robot.

The rests of this paper are organized as follows. We describe the proposed concept in the next section. In section 3, we describe the experimental setup and the results of the verification experiment without tasks for robots to check our concept. In section 4, we show the

Manuscript received May 4, 2021; revised August 1, 2021.

doi: 10.18178/ijmerr.10.10.536-541

experimental setup and the results of verification experiment with tasks for robots to confirm the appropriateness more clearly. Section 5 gives conclusion and future works.

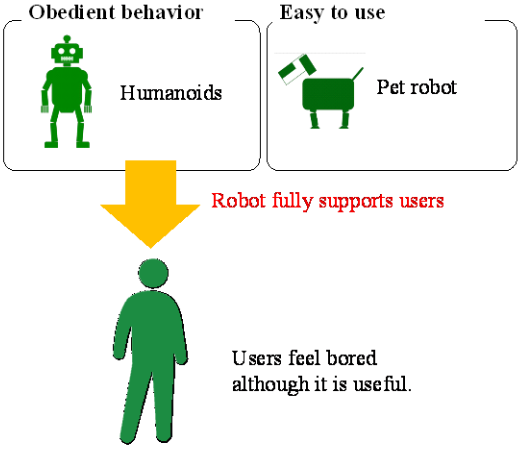

Figure 1. Typical situation when robots are used.

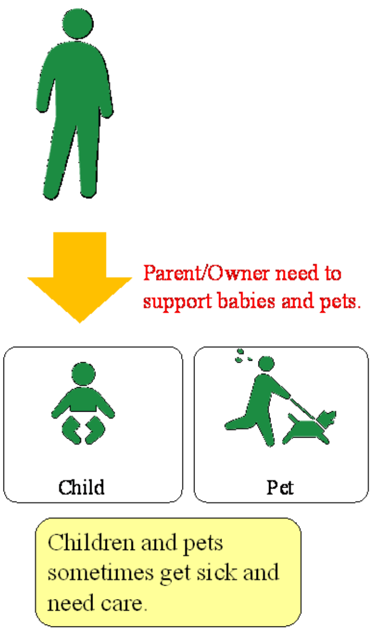

Figure 2. The situation when children and pets have sick.

II. Research Concept

This section describes the research concept of our approach. To clarify the target of our approach, we show some figures. Fig. 1 shows the typical situation when the robots are used. As shown in the above in Fig. 1, the robot is generally expected to fully support users. They are expected to be obedient and easy to use for humans. Of course, such types of robots are useful. However, users will be forced to behave passively. As robots continue to support users for a long time, users tend to get bored with their actions.

Humans and pets are not always perfect. They need to rest and help from parents/owners if they get sick as shown in Fig. 2. Parents and owners need to take care of them. However, due to their hardships, they become more attached to their children and pets. Fig. 3 shows the supposed scenario of the proposed robot design.

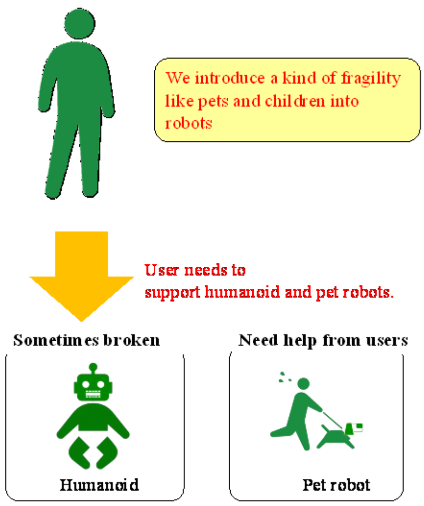

Figure 3. Supposed scenario of the proposed robot design.

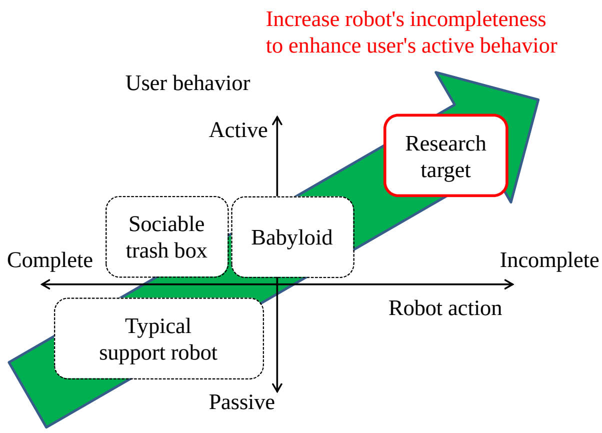

Figure 4. Our research target and other approaches.

As shown in Fig. 3, we introduce some kind of fragility to the robot. The fragility of the robot creates the need for the user to take care of the robot. As a result, we expect fragile robots to elicit user attachment. Fig. 4 shows the relationship between this study and related studies. As shown in Fig. 4, we expect robotic imperfections to encourage more active behavior for users.

III. Verification Experiment without Task for Robot

A. *Experimental Setup*

We examined whether a fragile robot leads to user attachment. A simple exterior was attached to the robot in order to produce the effect that the robot would break.

Fig. 5 and Fig. 6 show the appearance of the robot when the exterior is removed and when the exterior is attached, respectively. The exterior consists of four parts on the side that can be removed with an electromagnet.

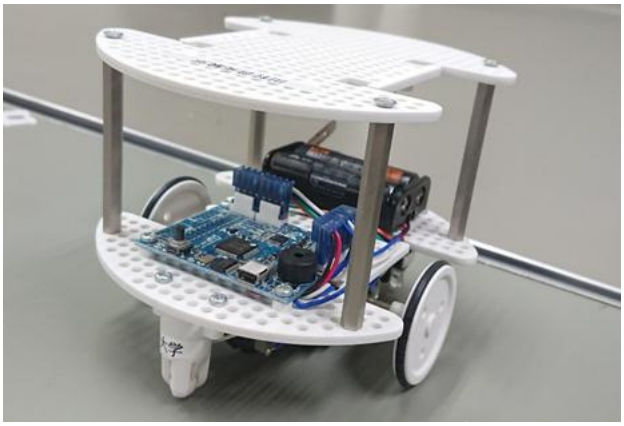

Figure 5. The appearance of the robot without the armor for the first experiment.

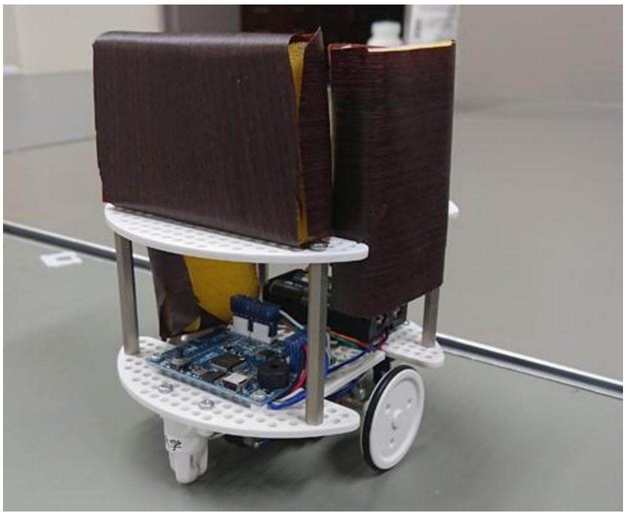

Figure 6. The appearance of the robot with the armor for the first experiment.

Each part is composed of a sponge with a clip attached. It can be attached and detached by turning on and off the electromagnet. In the experiment, a robot that breaks is produced by controlling the attachment and detachment of the exterior.

The design of the robot was kept simple and made as inorganic as possible so that the impression of the robot would not be influenced by other factors.

The robot is connected to the control computer by wire.

The on / off of the electromagnet can be controlled from the control computer, and the parts can be dropped by turning off the electromagnet.

By using the control computer, the operator can perform five operations on the robot: straight forward, backward, right turn, left turn, and stop.

B. Experiemental Procedure

The experimental process of the first experiment is described as follows:

TABLE I. ITEMS IN QUESTIONNAIRES

Question	Scale		
	Negative		Positive
Did you find the operation of the robot pleasant?	1	…	7
Did you get tired of the robot?	1	…	7
Did you find the robot cute?	1	…	7
Did you feel attached to the robot?	1	…	7
Did you want the robot ?	1	…	7
Are you interested in the robot ?	1	…	7
Did you feel familiar with the robot?	1	…	7
Did you want to be with the robot?	1	…	7
Have you been healed by the robot?	1	…	7
Did you like the robot?	1	…	7

1) The subject was asked to freely operate the robot using a control computer without telling the subject about the purpose of the experiment.
2) In the middle of the operation, one exterior is randomly removed in the time range of 30 to 60 seconds. After that, the examiner asks the subject to pick up the exterior and attach it to the robot.
3) When the exterior is removed from the robot, the subject is asked to reattach the exterior 5 to 10 times. After that, a questionnaire was given to the subjects regarding the impression of the robot.

The SD scale method was used for the evaluation. In this experiment, 10 adjectives were evaluated on a 7-point scale. In addition, we asked them to describe their impressions of the entire experiment in a free description format. Detailed items of the questionnaires are shown in Table I. In the experiments, we asked users to select 7 when they feel positive impression on the questions, while to select 1 when they feel negative impression on the questions.

Seven subjects participated in the experiment. The experiments were conducted after approval of the University of Electro-Communications Ethical Committee, where the principal investigator belonged.

C. Experiemental Results

In order to measure the significance of the experiment, a test using the t-test was performed. Items marked with * in Fig. 7 are items for which a significant difference was confirmed at the level of 5%.

From the experimental results, there were significant differences in the five categories of "pleasant," "unwearied," "attached," "interesting," and "familiar."

The result suggests that the impression of the robot can be improved by destroying the robot and eliciting the active behavior of humans.

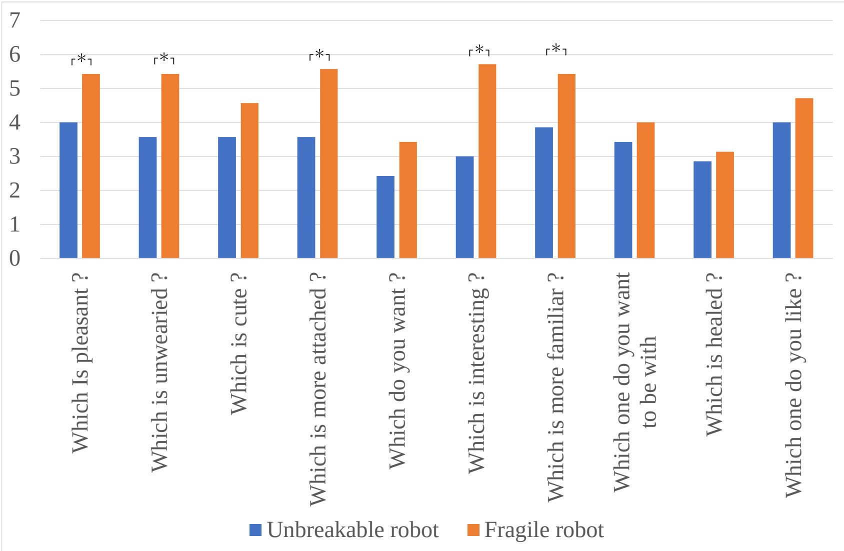

Figure 7. Questionnaire results of the first experiment.

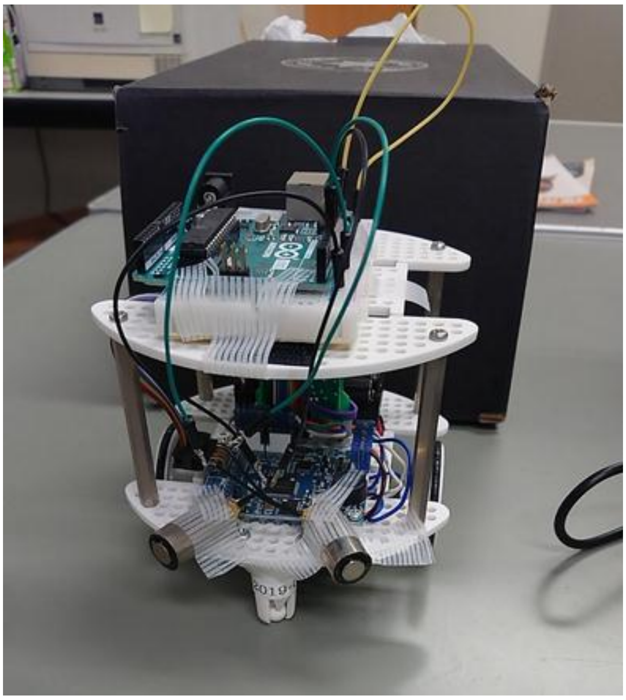

Figure 8. The appearance of the robot without the armor for the second experiment.

Compared to the case where the robot does not break, the average value of the questionnaire is higher for all items. It was confirmed that the subject's positive impression of the robot was enhanced by the factor that the robot broke. The experimental results did show a significant difference in attachment.

However, the results of this experiment may have been improved due to the addition of repairs to the work of moving the robot for no purpose. To check this point, we conducted another experiment.

IV. Verification Experiment with Task for Robot

A. Experimental Setup

We prepared another robot to perform an experiment with a task. The design of the robot was changed assuming the transportation of balls using a robot.

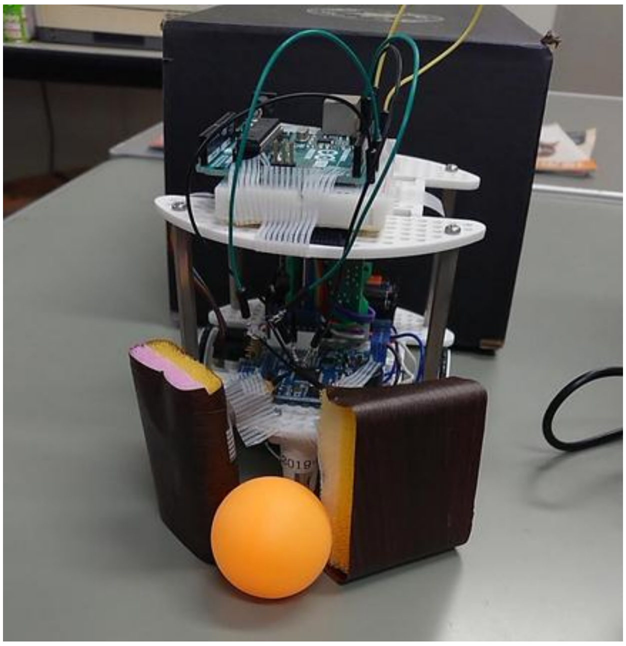

Figure 9. The appearance of the robot with the armor for the second experiment.

Two exteriors were attached to the front of the robot used in the experiment in the previous section.

Fig. 8 and Fig. 9 show the appearance of the robot when the exterior is removed and when the exterior is attached, respectively. The exterior consists of four parts on the side that can be removed with an electromagnet.

B. Experiemental Procedure

The experimental process of the second experiment is described as follows:

1) We asked the subject to operate the robot using a control computer without telling the subject about the purpose of the experiment. We asked the user to carry the ball to the goal about 5 meters away by using the parts on the front of the robot.
2) While the user is operating the robot, one exterior randomly comes off from the robot and falls off. The fall time was set between 10 and 30 seconds.
3) Until the user can use the robot to carry the ball to the goal, the user reattaches the exterior to the robot each time the exterior falls off the robot.
4) After the experiment, a questionnaire was given to the subjects regarding the impression of the robot.

The same questionnaire as in the previous experiment was used. Seven subjects participated in the experiment. The experiments were conducted after approval of the University of Electro-Communications Ethical Committee, where the principal investigator belonged.

C. Experiemental Results

In order to measure the significance of the experiment, a test using the t-test was performed. Items marked with * in Fig. 10 are items for which a significant difference was confirmed at the level of 5%.

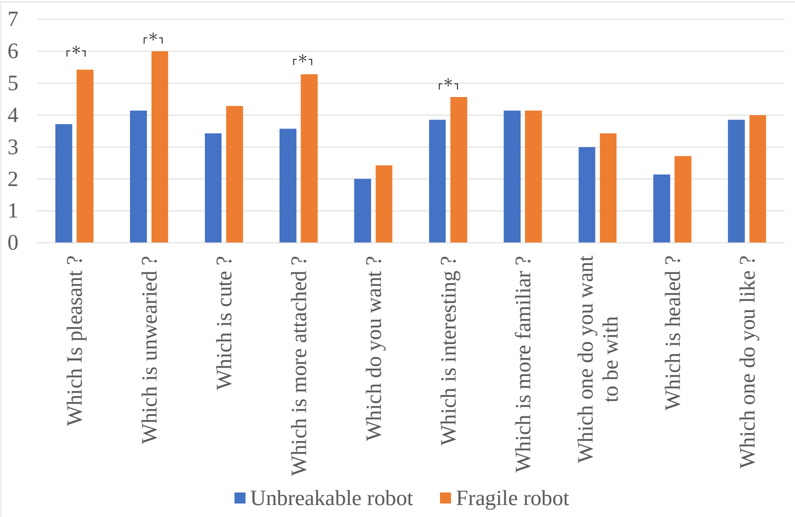

Figure 10. Questionnaire results of the second experiment.

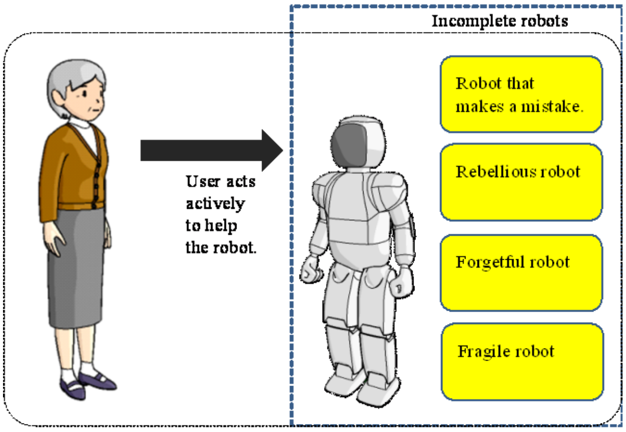

Figure 11. Design concept of imperfect robot that continues to attract users.

From the experimental results, there were significant differences in the four categories of "pleasant," "unwearied," "attached," and "interesting". These results suggest that even if the subject moves the robot with a purpose, the fragility of the robot leads to a better impression of the robot. It is noted that the difference between the average values of the unbreakable robot and the fragile robot was small for all items other than "fun" and "healed" compared to the experiment in the previous section. This is because the evaluation of the unbreakable robot was higher than in the previous experiment.

V. Conclusion and Future Works

In this paper, we proposed a fragile robot and its positive effects on human impression to the robot.

We conducted two experiments to check the validity of our concept. The first experiment was the verification experiment without tasks for the robot. The second experiment was experiment without tasks for the robot.

In both cases, we confirmed that the fragile robot gave positive effect of users' impression to the robot.

Through several experiments not only of this study but also of our previous studies, we think that the negative behaviors of the robots have potential to induce users' attachment to the robot. We need to further studies for total design of imperfect robot that continues to attract users as shown in Fig. 11.

Combining robotic mistakes and forgetfulness with this study may lead to attachment in longer-term interactions. In the future, we would like to conduct further experiments and confirm the effect. It is also necessary to investigate the appropriate percentage of fragility of robot operation.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Mitsuharu Matsumoto directs the research and wrote the paper.

ACKNOWLEDGMENT

The author wishes to thank Mr. Hiroki Tamura. This work was supported in part by the research grant of Support Center for Advanced Telecommunications Technology Research and by the research grant of Foundation for the Fusion of Science and Technology.

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