A Robot as "Receiver of Care" in Symbiosis with People

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1 Introduction

At present, industrial robots make up the largest share of the robot market. In the future, however, growth can be expected in the field of human symbiotic robots, that is, robots that coexist with people, such as "domestic robots" for communication, education, and entertainment applications and "service robots" for welfare/caregiving, rescue, and infrastructure-maintenance applications.

Human symbiotic robots are required to have the following features:

1. **Functionality:** In addition to basic robot functions, they must have functions essential to interaction. i.e., speech recognition and synthesis and image recognition.
2. **Stability:** They must be capable of stable interaction with people.
3. **Robustness:** They must be able to adapt and cope in a flexible manner even in an environment with uncertainties.
4. **Usability:** They must have an affinity to people and the environment not just in appearance but also in gestures and behavior.

Human symbiotic robots are therefore different from industrial robots, and must be able to coexist in the environment in which people live and have an interactive relationship with people. An interaction-oriented design that strongly appeals to a person's feelings is especially important for therapeutic robots that aim to heal a person's broken spirit. An interactive relationship between a person and robot can be formed through skillful interaction between the system in which the robot processes information received from the person and the system in which the person processes information received from the robot. In therapeutic robots, these two systems can be viewed as a function for understanding a person's feelings and a function for drawing out a person's feelings. Thus, a robot having the latter function for prompting emotional responses is called a therapeutic robot.

"Paro," a mental-commitment robot in the form of a baby harp seal, is an animal-type robot that can be used in healthcare activity for the elderly to promote healing and pleasurable sensations through the petting of an animal. It has been reported that the use of Paro can have physical effects such as stimulation and relaxation, psychological effects such as reassurance and emotional expression, and social effects such as activation of communication and group cohesiveness [1]. "Yorisoi Ifbot," meanwhile, is a companion robot developed to stimulate brain activity and to alleviate loneliness in the elderly through simple conversation. A research report on healthcare activity for the elderly using Yorisoi Ifbot has been issued [2]. The smile supplement robot "KABO-chan" has a conversation function as well, but it also has exercise functions and game functions including "raise the flag" and "pose" games. KABO-chan has been shown to be effective in improving cognitive skills and relieving fatigue and to be therapeutic overall [3]. "Babyloid" is a baby robot designed to be incapable of doing anything on its own. It can have a therapeutic effect by inducing in an elderly person a feeling of wanting to take care of it and of having something to live for by doing so [4, 5]. These four robots are mainly targeted at the elderly, but an interactive robot named "Keepon" having the form of a stuffed toy has been developed to care of children affected by autism [6]. In the above ways, therapeutic robots are being used in a variety of scenarios.

In this paper, we take up Babyloid as one type of therapeutic robot representing a human symbiotic system and describe its design and effects.

2 Babyloid

2.1 Background

Japan's elderly population, those aged 65 or above, grew to 33 million in 2014, the largest in the country's history. The proportion of the aging population out of the total population was 26.0 percent. Since 2013, we have been living in "super-aged society" in which one-fourth of its people will be elderly [7, 8]. It is critical for the elderly to perceive the value of their own existence in the midst of such successive aging of population structures and live with a purpose in life, while taking into account their deteriorating functions and changing roles.

For the elderly to feel purpose in their lives, active interactions with the outside world, including through the form of work, is considered a necessity. Thus we considered providing an impetus to old age people to feel purpose in living by giving them the social role of caregiving through living together with a robot, the object of care. In this study, we describe the development of a robot called Babyloid for this purpose [4, 5].

2.2 Interaction Design

When we speak of human-robot interactions, we tend to think of a framework in which the robot reads human inputs, such as emotions and requests, and carries out responses as output. However, aspects of human-robot interactions differ in the case of a "robot being cared for" that we seek to develop. In other words, the care-receiving robot gets human beings to understand and receive its emotions and requests. If this aspect is emphasized, giving and receiving sensible information in interactions can be carried out by transmitting information based on how the robot is embodied and on diverse interpretations by humans on the receiving side. We believe that a more appropriate material form for a robot that only transmits such information is that of a human baby. This is because a human baby has advantages including: (1) he or she is allowed one-way interactions (this is considered common knowledge), (2) he or she is a symbol of a care recipient who cannot do anything, and (3) he or she can present diverse information with expressions and noises.

2.3 Design Concept

Babyloid is a robot whose purpose is to relieve the psychological stress of elderly people and patients needing long-term care by having them take care of it. Unlike general robots, which seek to be able to do all the tasks in the manner of human beings, Babyloid was designed so that it cannot do anything. However, it tries to satisfy its self-sufficiency by expressing psychological and physiological conditions through crying, showing bad mood, etc. Self-sufficiency is the ability of animals to sustain themselves over the long term [9]. In the case of a robot, for example, it would include the ability to provide itself with fuel so it can maintain its battery level. Although there is the tendency to think that, intuitively, self-sufficiency is carried out by oneself as in the example above, in the real world there are many instances observed where it is fulfilled by others. An example is babies' method for self-sufficiency. A baby is absolutely dependent on his or her mother, and fulfills self-sufficiency by using the mother as intermediary. In other words, by expressing psychological and physiological instabilities and bodily discomfort through facial expressions and body movements, the baby gets his or her mother to observe his or her conditions and improve them. We focus on this fact, and seek to arouse the feeling of "I am taking care of someone" in users by introducing Babyloid's entreaties to take care of its discomfort in the interactions between the robot and people.

This outline of Babyloid requires a design of "not being able to do anything" like a human baby. It is critical to make visible the fact the robot cannot do anything [10]. Thus the robot (1) has no feet in order to indicate that it cannot walk, and (2) its arms are made short to indicate that it cannot perform actions like rolling over.

The motif of a beluga whale is used in the design of Babyloid's face. By personifying an animal, unpleasant expressions are restrained, while biases toward existing characters are eliminated. By adopting a neutral animal and machine design, we seek to create a robot that makes a good impression on people. Also, taking into account the sensation of touch, we made the body of the robot soft, and made sure that the design exuded warmth.

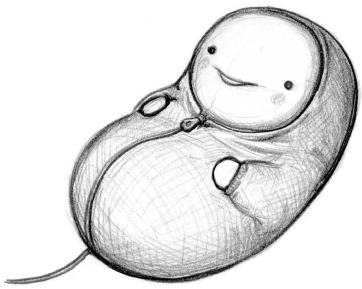


Figure 1: Design drawing of Babyloid.

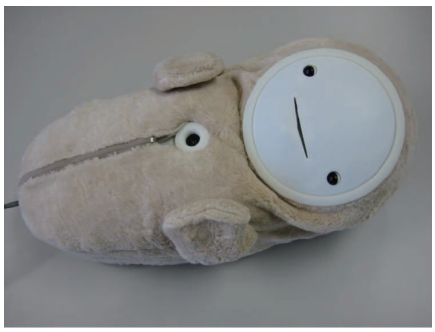


Figure 2: View of Babyloid.

Figure 1 shows a design illustration incorporating the points above.

We developed Babyloid based on the concepts and design discussed above.

3 Specification of Babyloid Prototype

3.1 Design of Body

Figure and 2 show the exterior of Babyloid. Its length is about 44 cm and its weight is about 2.2 kg. By making it slightly smaller than a human baby, we make it easy for an elderly person to hold it with his or her strength.

To make it lightweight, the body is made of resin. The body is created by using Selective Laser Sintering (SLS) based on 3D data. In this process, laser is directed to resin powder and sinters layer by layer to build up the layers of the body. With this method, we could design a body that is robust against bending and drops. By covering thpe body with mohair, we made it soothing to the touch (see Figure 2).

3.2 Babyloid's Mechanism: Trunk of Body

Figure 3 shows Babyloid's mechanisms. Two

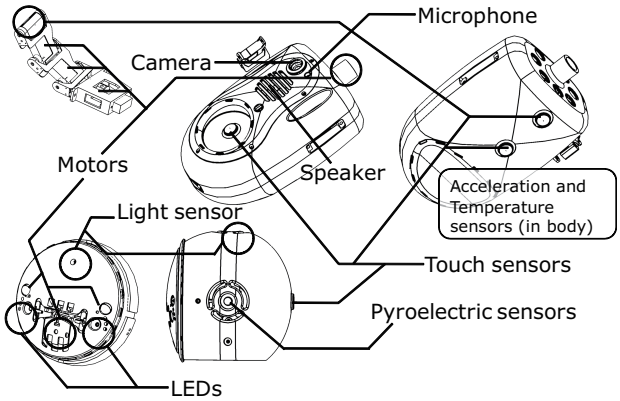


Figure 3: Mechanisms of Babyloid.

motors are placed in the neck, which allow flexion/extension and rotation. Three motors are placed in each of the two arms. They allow the shoulders to flex/extend and adduct/abduct, and elbows to flex/extend.

For interactions with the external world, touch sensors are placed in the robot's hands, the stomach, and the back (two spots). They can detect conditions including when Babyloid is held, when its hands are gripped, and when it is placed on a bed for sleeping. Also, depressions are made in the stomach and buttocks and filled with low rebound materials. In this way, the stomach and buttocks feel soft as they do in human beings.

Babyloid can recognize the surrounding environment using a camera and microphone, and can express voice with its speaker. The voice used is created by sampling the voices of a human baby about one year of age. Human babies of this age often still cannot talk, but their voice may sound like it includes words. By using such a voice, we can draw diverse interpretations from people, and create psychological interactions. Also, a feature of babies at this age is their imitation of words spoken by people around them, and their repetition of these imitations. Because Babyloid has the function of recognizing single words, it is designed so that it can respond with a mimicking voice when it recognizes a voice uttering words it is capable of repeating.

An accelerometer and a temperature sensor are placed inside Babyloid. The accelerometer can detect

sudden changes in speed, for example when Babyloid is rocked or when it falls. The temperature sensor can be used to detect the deterioration of its own internal conditions in order to fulfill self-sufficiency.

3.3 Babyloid's Mechanism: Face

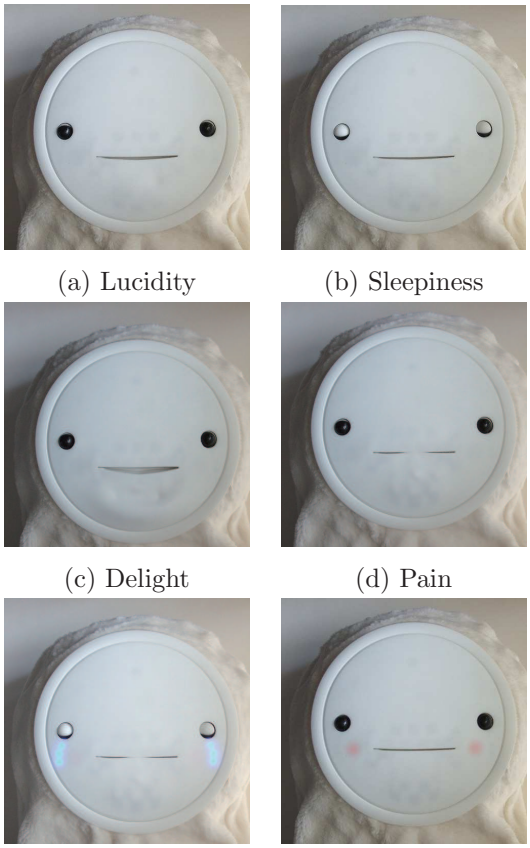
The face is made of silicon resin 1.5 mm thick. Silicon resin is stretched by motors in the mouth and jaw region to create expressions. Eyes are also rotated by motors, so their opening and closing can be expressed.

Because LEDs are placed in the cheek regions, tears and blushing of cheeks can be expressed. This allows emotionally-rich expressions. However, if users can see through the skin of the face and see the mechanisms, they would feel discomfort. Therefore the silicon resin is not highly transparent. Therefore, the LED lights appear faintly on the face.

Figure 4 shows examples of expressions. These expressions are achieved by combining the movements of motors to their greatest possible extent with turning LED on and off. Each expression is labeled subjectively by the authors.

Light sensors are placed in the forehead and the top of the head. Thus Babyloid can respond, for example, when it is patted on the head.

Pyroelectric sensors are placed in the regions corresponding to the human ear regions. These sensors allow Babyloid to determine the existence of people around it.



(a) Lucidity (b) Sleepiness (c) Delight (d) Pain (e) Sorrow (f) Shyness

Figure 4: Facial expression examples of Babyloid.

4 Experiment

4.1 Purpose

To evaluate the state of acceptance and rejection of Babyloid by building a shared living space for Babyloid and elderly subjects, and observing occurrences of intentional actions by the elderly users.

4.2 Subjects

The subjects were five women who were residents of a welfare facility for the elderly and who received a score of 30 on the Mini-Mental State Examination (MMSE) [11]. The characteristics of each subject is shown in Table 1. MMSE is a questionnaire survey for measuring cognitive functions and memory ability. Its full score is 30 points. A score of 21 or below indicates a high possibility of cognitive impairment, such as dementia. For our experiment, we surveyed the state of Babyloid's acceptance and rejection. Thus we chose subjects whose cognitive functions have not declined. Impaired cognitive functions include (1) easily accepting non-living objects, and (2) having difficulty becoming tired of doing something as a result of forgetting what one has done.

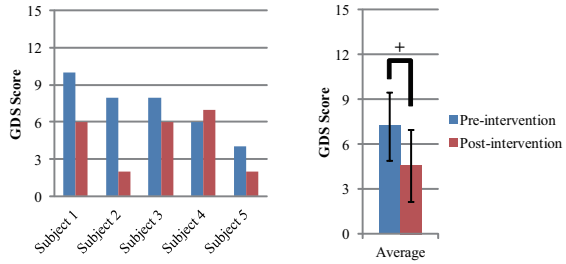
4.3 Evaluation Items and Timing

The experimental period was two weeks per subject. During this time, Babyloid was placed in the subject's personal room, and activated for an eight-hour period. The subjects were not forced to interact with Babyloid. They were instructed to use the robot only when they wanted to.

The evaluation items were (1) the Geriatric Depression Scale (GDS) [12, 13], (2) the Face Scale [14], an interview survey, (4) behavioral observations, and (5) MMSE. The GDS score is an indicator measuring the

Table 1: Subject Characteristics.

Subject No.	Sex	Age	MMSE
1	Female	72	30
2	Female	76	30
3	Female	75	30
4	Female	73	30
5	Female	68	30
		72.8±3.1	30



(a) Each subject (b) Average

Figure 5: GDS Score

level of depression. Its score range from 0 to 15, with 15 as the full score and a score of 5 or above indicating a state of depression. The Face Scale measures a person's mood at the time of the survey. The original Face Scale presented 20 expressions. However, based on previous research that found that elderly subjects were bewildered when responding [1], for our test, we used seven expressions similar to the original expressions. Therefore, 4 points were set as the middle value. A lower score is taken as indicating good mood.

Each evaluation item was carried out according to the timing below.

GDS survey: The survey was taken before the testing period. By doing so, we could study the effects on Babyloid on depression.

Face Scale survey: This survey was taken every time after the subject used the robot. From changes in the value of the Face Scale, we could track changes in daily mood.

Interview survey: Interviews were conducted after the end of the testing period. From the responses, we could qualitatively evaluate interactions with the robot.

Behavioral observations: Observations were conducted using the robot's sensors (camera, microphone, touch sensors, pyroelectric sensors, light sensors, accelerometer, temperature sensor). Thus, monitoring devices (e.g. video camera) besides those used in Babyloid were not placed in the subjects' rooms. Also, the robot's startup times were also recorded.

MMSE survey: This survey was conducted before the testing period in order to understand the cognitive functions of elderly patients and to select subjects.

4.4 Ethics

The content of the research study described in the previous section was approved by the Chukyo University Ethics Committee. Also, the following information was explained to research subjects, from whom we received consent to participate in this research study: purpose and content of the research study; content of camera video recordings, voice recordings, and sensors during interactions with Babyloid; protection of personal information; and the right to refuse or withdraw from participation.

5 Evaluation Results

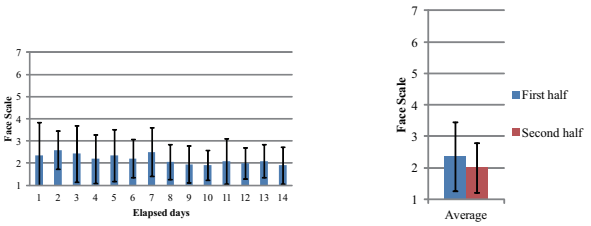
5.1 Effect on Depression (GDS Survey)

Figure 5(a) shows the GDS score for each subject. Figure 5(b) shows the average GDS score. As shown in Figure 5(b), a statistically significant difference ($p = 0.078$) could be seen before and after the testing period. This result suggests that being involved with Babyloid could reduce the level of depression.

5.2 Effect on Mood (Face Scale Survey)

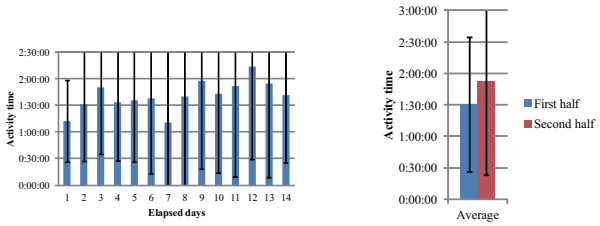
Figure 6(a) shows the daily average of the Face Scale. The graph suggests that the mood after interaction with Babyloid was extremely good.

Next, we divided the testing period into the first half (day 1 to day 7) and the second half (day 8 to day 14), and evaluated the change in the Face Scale score. The results are shown in Figure 6(b). A statistically significant difference could not be seen, however, the Face Scale score tended to decrease.



(a) Daily avg. (b) First/second half avg.

Figure 6: Face Scale



(a) Daily avg. (b) First/second half avg.

Figure 7: Activity time per day

Table 2: Activity time per interaction.

	Mean	SD
Subject 1	6:42	3:29
Subject 2	7:36	3:13
Subject 3	8:25	2:54
Subject 4	8:04	3:11
Subject 5	3:37	1:46
Average	6:53	2:55

5.3 Survey of State of Apathy (Duration of Activity with Robot)

First, Table 2 shows the duration of activity with Babyloid each time an elderly subject interacted with it. Time spent with Babyloid was considered an interaction if it lasted 30 seconds or more. The table shows that an average of 7 minutes was spent interacting with Babyloid each time.

Next, we examined the total amount of activity time per day. Figure 7(a) shows the average per day. Because no great reduction in the duration of using Babyloid could be seen throughout the two weeks, we could confirm that the subjects did not immediately become tired of the robot. Also, similar to the Face Scale evaluation method, we could not observe a statistically significant difference in the duration of activity between the first half and the second half of the testing period (see Figure 7(b)). However, there was a tendency for the activity time to increase. We should note here that many subjects spent more than one hour per day using Babyloid and being in contact with it. Because we did not force the use of Babyloid during this experiment, this result suggests that the subjects sought on their own volition to be actively involved with the robot.

5.4 Qualitative Evaluation Using Interview Surveys

We investigated the psychological effects of Babyloid on the subjects by interviewing the five subjects as well as facility staff.

Of the five subjects, four evaluated Babyloid positively, and one subject did not evaluate it positively. That subject was Subject 4. As could be seen from Figure 5(a), improvement in her depression could not be seen. However, the reason for Subject 4's lack of positive evaluation could be strongly due to the experimental procedures and her personality (a serious personality and one that dislike changes, so the experiment itself was a great psychological burden on her). Thus we believe that it is possible she could evaluate her involvement with Babyloid positively depending on the form of the experiment (if it did not change her life pattern too greatly).

Of the four subjects who gave positive evaluations, three (Subjects 1, 2, and 5) stated that involvement with Babyloid had a "healing" effect, a level that surpassed "fun." We believe this is because Babyloid's voice (laughing voice) has a comforting effect. Each subject also described their daily lives with Babyloid. We confirmed diverse styles of addressing Babyloid. For example, the subjects sang to it, watched television together, called out to it when going out and going to bed, related events of the day (happy and sad incidents) to it, and spoke a few words to it when they woke up in the middle of night. Such interactions could be considered to produce a kind of counseling effect. While Babyloid might not have made a response to addresses by the subjects, it did not express responses denying what the subjects said. Thus the subjects could safely express their own thoughts

to Babyloid. We believe that this is a reason the subjects felt a deeper sense of "healing."

From these evaluations, there is the possibility that for three subjects, Babyloid was not simply a "baby-model robot," but existed as a type of life partner who could transform daily life into a fulfilling one.

6 Conclusion

In this paper, we described a human bymbiotic robot Babyloid as "receiver of care".

Caregivers are carrying out activities for the elderly in health and welfare facilities to complement lost functions and to suppress the deterioration of functions that they possess. These preventive activities include music therapy [15, 16], art therapy, horticultural therapy [17], and sports therapy. Specifically, the activities being carried out include choir singing and musical performance, craft activities like knitting and making ornaments, and bodily recreation such as calisthenics, walking, and playing games. Also, to improve sociability and psychological well-being, animal assisted therapy (AAT) and animal assisted activity (AAA) are being implemented with the goal for providing healing and pleasure from contact with pets. Their benefits have been observed [18, 19]. However, because keeping pets by old age people presents a variety of issues, efforts on robot assisted activity (RAA), using robots instead of pets, have begun in recent years [20, 21, 22]. Robots do not harm people under long-term care as animals can, and the possibility of them as vectors of infection is extremely low. Taking care of them also do not require burden in the area of safety. Furthermore, disciplining and training are not needed, and anyone can always use a robot in the same way, anytime.

The various preventive activities listed above seek to build communication between elderly patients and family members and people in their environment, as well as to provide pleasant stimulus from the environment. The diversity in these preventive activities is due to differences in individual elderly patients as to what satisfy their hearts. From such conditions at the nursing care sites, we believe that robots should not simply be treated as a substitute for pets, but can create relationships beyond what animals are capable of by performing roles that only robots can perform to satisfy the elderly users' hearts. Thus we sought to develop Babyloid, whose role is to receive care. In addition to effects similar to AAA and RAA, our developed robot is expected to have doll therapy's effects of mitigating the insecurity and the depressive mood of elderly patients with dementia and calming them down [23] Also, we can expect the effect of users raising the robot, which cannot be obtained with animals. Thus Babyloid can be applied to elderly people living alone to prevent isolation. In addition, the robot can be applied to relieving their loneliness and improving their sociability. Fields to which we can extend the development of the robot include childcare training for expecting mothers by using robots to simulate babies, and moral education of elementary school children.

As described above, the robot can be applied to a variety of uses if we note the fact that it is not to be taken just as a baby, but that it also brings about the effects that babies do of providing stability to the heart and stimulating psychological effects in people by demanding care.

Babyloid is expected to promote greater psychological exchange in people than baby dolls.

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