What makes people accept a robot in a social environment
- discussion from six-week study in an office -

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***Abstract*— In the near future, robots are expected to play active roles in human communities. After this time arrives, robots will need to be socially accepted by the people in the communities to which they belong. However, it remains unknown what issues must be resolved to make robots socially accepted. In this paper, we point out the three criteria with which people in communities evaluate a robot and three types of relations people have with the robot. We conducted a six-week study in an office to statistically test the relationship between the evaluations and how well a robot is accepted depending on relation types. We probe that by improving behaviors in the criteria the robot will be more accepted by each type of people. Then, the discussion are presented about the most important issues regarding the social acceptance of robots.**

I. INTRODUCTION

In the near future, robots are expected to play much more active roles in such human community settings as schools, museums, offices, and so on. At that time, robots must socially be accepted by the people in the communities to which they belong so that it can smoothly play its role. Then, the question is how a robot should behave in the communities or how a robot develops human-robot relationships.

A number of long-term studies have been conducted regarding the performance of robots in everyday settings. Jijo-2 [5] was developed for use in offices to guide visitors, offer the location of a members, and so on. A museum-guiding robot [1] and an expo tour-guide robot [10] have also been developed. However, they assumed that the robot is accepted if it plays its role in the community but did not care for the human-robot relationship.

To investigate how children interact with a robot, long-term studies have been conducted in a kindergarten [7] and an elementary school [8]. They mainly focused on one to one direct human-robot interactions of children but not focused on other types of relationship.

We also conducted a study in which a robot daily communicated with the people in our office and wandered around for a certain period looking for a conversation partner [6]. After finding someone to talk with, it started a conversation. The study investigated how effectively the robot's human-robot interaction behaviors offered the people in the office a sense of familiarity with it.

As a result, questionnaire responses suggested that the robot was welcomed since people had a sense of familiarity with it. We also received negative feedback that reflected two major drawbacks. One, the robot tried to communicate with others without considering time, location, and their current mood. Second, some regarded the robot had no social reason for staying in the office since its only function was to chat. Although chatting is an important social role for a therapeutic and entertaining robot, they did not want it in the office. Such feedback indicated that people evaluated the robot in their community by the following three criteria: how much it provides a sense of familiarity, how appropriately it behaves based on the circumstances, and how well it plays its social role in the community.

The result also indicates that there are three types of relationship between a human and a robot. One is the relation that they directly interact, such as, the human asks the robot for a task to complete. Second one is less direct in that the human does not directly interact with the robot but sees some interaction of other people and the robot. Third one is indirect relationship that the human rarely sees the robot and he/she knows the robot mainly by hearsay knowledge. Previous work [6]–[8] implicitly assumed a small community that most members have direct interaction experience with the robot. However, the number of the second and the third type people increases in a larger community.

In this paper, we investigate how a robot is socially accepted by the following steps. First, we explore how a robot is accepted in a community. A six-week study in our office was conducted to gather evaluations of a robot and its acceptance. After that, we statistically analyzed the relationships between three criteria and the degree of acceptance. We show that there are differences in them depending on the types of human-robot relations above. Following the study results, we discuss the issues regarding the personal acceptance of robots. Then, we discuss how a robot is socially accepted by a variety of community members and the most important issue for a robot to be socially accepted.

In the next section, we briefly introduce our previous study and its results. After discussing how people evaluated the robot, we introduce three evaluation criteria for a robot to be accepted by community members and the three types of human-robot relationship.

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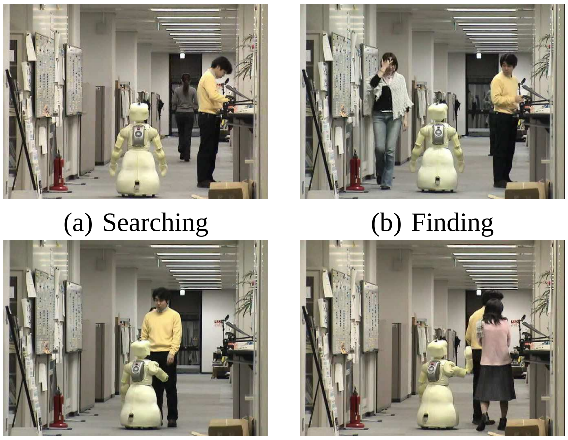

(a) Searching (b) Finding

(c) Talking (d) Ending

Fig. 1. Robovie-IV's typical interaction flow: searching for a human and talking

II. Evaluations of a robot

A. Observations from a six-month study

We conducted a study to investigate how people evaluate a robot's communication behaviors in an office when meeting it every day [6]. The robot's behaviors, which were designed to create the people in the office a sense of familiarity with it, resembled a child accompanying a parent to the office. Such a child is warmly treated by adults in the office if he/she behaves appropriately. The robot imitated such behaviors to be accepted in a similar way in the office.

For six months, Robovie-IV, a communication robot, moved around in a corridor and searched for chatting partners for about 90 minutes each day in a corridor about 50 meters long in our ATR IRC laboratory's office. About 30 to 50 people, both full-and part-time, were working in the office.

Fig. 1 shows the flow of Robovie-IV's typical interaction. It searched for a human to talk with (Fig. 1(a)). After finding a human, it began interaction by saying "hi" and waiting for a response (Fig. 1(b)). If it did not receive a response, it began to seek another human; otherwise, it recognized the human as an interaction partner and started a conversation, as shown in Fig. 1(c). The conversation ended when he/she said "good-bye" or walked away. Then the robot responded with "good-bye" and began to seek another conversation partner (Fig. 1(d)).

After the six-month study period, we asked the people in the office to fill out questionnaires by e-mail. We got thirteen responses from people who frequently interacted with or saw the robot. Five of these thirteen had positive impressions of the robot in the office, two were neutral, and six had negative impressions. Some responses to the free-answer questions indicated positive impressions of the robot's behaviors and a sense of familiarity with it. Examples include: a) "talking with Robovie was relaxing" and "when talking with Robovie, one person took on a soft expression that I've never seen when he is talking with people in the office." However, other answers pointed out drawbacks, including: b) "it was nuisance in the office," "the robot always said "hi" to me when I was in a hurry," "it always tried to talk behind my cubicle and it's noisy" and c) "I expected a robot in an office to do something useful but it didn't." These responses indicate that people evaluated the robot based on three criteria: a) how much it produced a sense of familiar in others, b) how appropriately it behaved based on the circumstances, and c) how well it played its social role.

B. Three issues for accepting a robot

The questionnaire answers from the previous study suggest at least three issues that must be satisfied for a robot to be accepted.

a) *familiarity*: how much a robot creates a sense of familiarity,
b) *circumstance-appropriateness (c-app.)*: how appropriately the robot behaves depending on circumstances, and
c) *social-role*: how well it completes given task in the community.

The evaluation of each criterion and its importance will be different from person to person depending on the backgrounds and interaction experiences with the robot even within a single community. However, we expect that as the evaluation of each criterion increases, the more the robot will be accepted.

To examine the mutual relationships between the evaluations of each criterion and how well the robot was accepted (*acceptance*), we conducted a six-week study. Three different robot behaviors were prepared, and each was performed for two consecutive weeks. The behaviors were designed to elicit different responses to the *acceptance* and the three criteria above from the people interacting with the robot. Each week, we asked people to fill out questionnaires, which we used to measure the criterion and *acceptance* evaluations. The following are the three prepared behaviors: 1) moving around and talking with people regardless of location (*search-and-talk*, identical behaviors shown in the previous study), 2) mainly staying in a small area and only talking with people in that area and sometimes moving around but not greeting people in the corridor (*stay-and-talk*), and 3) mainly staying in a small area and only talking with people in that area and sometimes moving around in the corridor to deliver documents (*stay-and-talk-during-delivery*). The details of the behaviors and the study are described in the next section.

C. Three types of human-robot relationship

Here, we classify people into three types according to the interaction with the robot as in Fig. 2. The type X people are the ones who directly interact with the robot. For example, they chat with the robot, ask the robot for a guide, ask a deliver task, and so on. The type Y people have chance to see the robot and human-robot interactions of the people X but do not have direct interaction with the robot. People in the group Z rarely have chance to see the robot. They only have indirect (hearsay) knowledge from people X and Y.

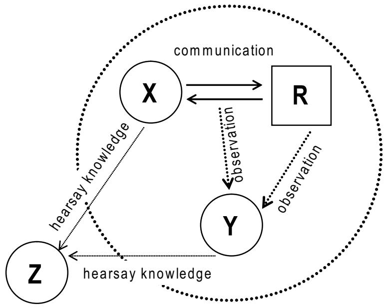

Fig. 2. There are three types of people from the viewpoint of human-robot interaction in a community. X has direct communication with the robot. Y observes the communication between X and the robot. Y has direct knowledge. Z only has hearsay knowledge about the robot.

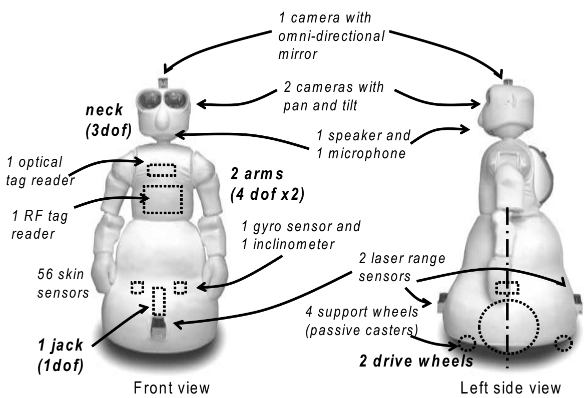

Fig. 3. Front and left side views of Robovie-IV. Fitted actuators and sensors are shown.

III. Study in an office

A. Robot and environment

Fig. 3 shows the front and side views of Robovie-IV, which is about 1.1 m high. It has two arms each with four degrees of freedom and a head with pan, tilt, and roll joints. Its voice is synthesized with CHATR [2] and sounds like a child. *Julian* [4] is adopted for the speech recognition engine.

We chose our office as the experimental field as in [6] for the following two reasons. First, it is a human community that involves people in different positions with different personalities and backgrounds. People spend many hours sharing space and experiences. Thus, we believe that the findings from studies in offices can be applied to many other human communities. Second, a robot is welcomed as a novelty when initially introduced to a community, but this feelings soon passes. A robot is only truly socially accepted after it has been welcomed without novelty. If we can run studies where people are already accustomed to the robot, we don't need to wait for it to lose its novelty. Therefore we chose our own office, since people are more accustomed to robots than in other offices.

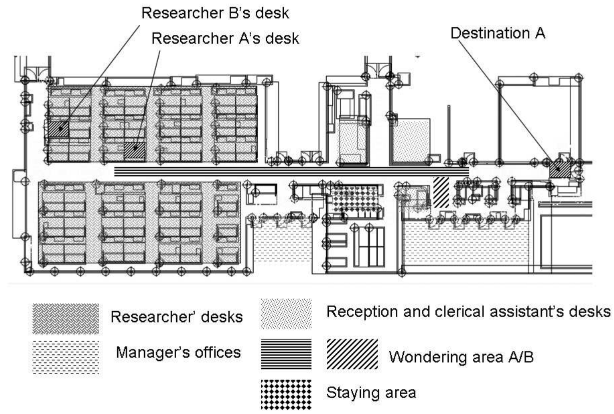

Fig. 4. Office floor used for the study: researcher cubicles, reception, clerical assistant desks, manager offices, and a long corridor

Fig. 4 shows the experimental environment in which about 60 researchers, clerical assistants, managers, and intern students work. About 15 people work near where the robot moves around since some work part time and others work mainly in other experiment rooms. The office floor includes researcher cubicles, reception, clerical assistant desks, manager offices, and a long corridor. Each cubicle is surrounded by partitions about 1.3 m high. The study ran from around 3:00 to 4:30 p.m. when people are still working but often take short breaks.

B. Procedure of the study

Three behaviors are prepared for the robot. It takes the same behavior for sub-sequent two weeks. A questionnaire is issued each week for the same people in the office to evaluate the robot's behavior. It is preferable to avoid order effects caused by the presentation order of behaviors. However, it is almost impossible to control the respondents since the environment is a real office.

Meanwhile, there is an idea to use different environments to avoid the order effects so that a respondent experience only one of the robot's behaviors. However, there are different possible problems such as respondents' familiarity with the robot and control of the environmental conditions.

Then, we decided to conduct the study in an office. The three behaviors are presented in the order as if the robot develops its behavior to suit for the office environment.

C. Robot behaviors

1) Search-and-talk behavior: In the first and second weeks, the robot searched for a conversation partner by moving back and forth in the "wandering areas A and B" in Fig. 4. It says hello and tries to talk with people anywhere in the area in a fashion identical to the previous study (Fig. 1.)

Basically, the robot repeats a) moving around, seeking a human to interact with; and b) interaction with the found human until he or she quits the interaction. It detects humans

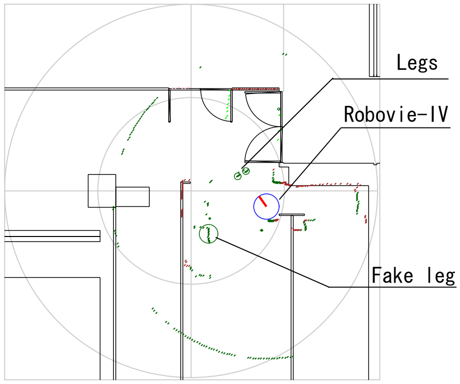

Fig. 5. A depth image plotted on the floor map by a laser range sensor. A circle and a line on the right indicate Robovie-IV's position and posture. Two circles in front of the robot are detected legs. The larger circle to the left of the robot is a false detection.

Fig. 6. Robovie-IV carries a bag in fifth and sixth weeks

by first finding leg candidates from front laser range-sensor values. The laser range sensor measures at the height of an ankle. Fig. 5 illustrates the readings of the range sensor plotted on the floor map. The circle on the right and the line indicates the position and the posture of the robot from self-localization data based on map matching. Clearly, the walls and cartoon boxes are detected by the sensor, whereas distant walls are not detected since the sensor's maximum range is 4 m. The two small circles in front of the circle representing the robot indicate detected legs. When a leg candidate is found, it rotates itself and gazes in the direction of the leg candidate. If a large skin-colored blob or a large blob in a differential image is detected by the robot's camera, or the tag reader detects a valid ID, it assumes the candidate to be a human leg. During interaction, it tracks the skin-colored blob at the shortest distance in the direction of the leg candidate and maintains that distance and posture.

Once Robovie-IV has detected a human, it will try to interact with him or her. It will say "Hi" in Japanese and wait for the response. If it does not detect a response it will begin to seek another human; otherwise, it will recognize the person as the conversation partner.

A conversation consists of several small topics that are comprised of a few pairs of sentences spoken by the robot and a set of expected human responses. Dictionaries for the speech recognition were prepared to cover the expected responses. Topics were always initiated by the robot. For example, it initiates a topic by saying "It's hot today, isn't it?"; "Do I look cute?"; "Are you hungry?"; "What are you drinking?"; and so on. Then it waits for an answer and continues the conversation by responding or starting another topic.

2) Stay-and-talk behavior: In the third and fourth weeks, the robot only talked in the "staying area," where it stayed for 10 minutes before making a lap in the corridor to "wandering area A" and returning to the "staying area." It searches for a conversation partner in the "staying area," as in the first and second weeks. It repeats "stay and move" until the experiment's time ends.

The "staying area," which was determined so that the robot does not disturb people working at desks or in cubicles, is equipped with electric pots, a refrigerator, and a cupboard for making tea or coffee on breaks.

The robot does not talk with anyone it encounters in the corridor. If an individual addresses it, the robot says "let's go to the break area and talk there" and returns to the "staying area." When it arrives there, it begins to chat with that person.

3) Stay-and-talk-with-delivery behavior: In the fifth and six weeks, the robot only talks in the "staying area," where it remains for 20 minutes before starting a "delivery task." The robot carries a bag to deliver a document in these two weeks (Fig. 6). As in previous weeks, it searches for a conversation partner in the "staying area" and repeats this "stay and deliver" behavior until the experiment's time ends.

The "delivery task" simulates a messenger's behavior in an office. The robot works for researchers A and B, who were chosen from our research group beforehand and asked to cooperate in our study. Their cubicles are located as shown in Fig. 4. First, the robot visits a researcher's cubicle and asks for a document to deliver. If there is one, the researcher puts it in the robot's bag, and the robot delivers it to destination A shown in Fig. 4. At destination A, the robot announces that a document has been delivered and asks for another document to deliver. The robot repeats this behavior for researchers A and B.

During this "delivery task," it does not try to talk with a human when it meets one in the corridor. If a human tries to talk with the robot, it says "Sorry, I am working now. Let's talk later" and continues its "delivery task."

D. Questionnaire

We put questionnaires in physical mailboxes at the end of each experiment week and also sent e-mails to the people in the office and asked them to complete the questionnaires.

The questionnaire asked the following:

1) *evaluations of robot:* Respondents were asked to mark the 7-point rating scales of sixteen adjective pairs in Table I. One adjective in the pair is placed at 1 in the scale and the other is placed at 7 (Fig. 7).
2) *interaction experience:* Respondents were asked how frequently they met and talked with the robot during the week.

TABLE I

ADJECTIVE PAIRS USED IN QUESTIONNAIRES FOR ROBOT EVALUATION

Positive adjective	Negative adjective
cute	not cute
amusing	boring
amiable	not amiable
warm	distant
thoughtful	inconsiderate
quiet	noisy
robot is aware where it is	unaware
not-obstructive	obstructive
responsible	irresponsible
diligent	lazy
earnest	excessive
honest	slipshod
likeable	unlikable
active	passive
quick	slow
lively	not lively

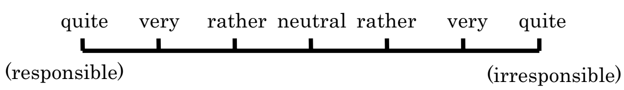

Fig. 7. Example of a 7-point rating scale of adjective pairs

3) *changes in robot:* We asked whether respondents had noticed any differences in the robot from the previous week, and if so, to explain that impression.
4) *how the robot was regarded (respondent's view of robot):* Respondents were offered 14 choices to match how they regarded the robot: unfamiliar creature, pet, friend, servant, child, adult, toy, machine, AI, automatic responding machine, a thing that you have technical interests (technical interests), a thing that you have interests in conversation (interests in conversation), a robot in which you have technical interests (interests in robots), and other. Respondents were allowed to mark more than one choice.
5) *how well the robot was accepted (acceptance):* Respondents were asked to mark the 1-7 rating scale for the following question: "Do you want the robot to stay in the office?" 7 corresponds to definitely yes and 1 to definitely no.

IV. RESULTS OF THE STUDY

Twenty three people, 12 males and 11 females, returned 76 questionnaires. Twelve of the 23 people (3 males and 9 females) answered the questionnaires for all three robot behaviors. In other words, twelve people returned questionnaires once or twice every two weeks. Table II breaks down respondents by occupations and ages. The interns, researchers, and managers have some knowledge about current computer and robot technologies. Clerical assistants use computers but are unfamiliar with programming and robot technologies. In the following, scores are averaged before analysis if a respondent answered the questionnaire twice for the same robot's behavior.

TABLE II

OCCUPATIONS AND AGES OF 23 RESPONDENTS WHO RETURNED QUESTIONNAIRES FOR ALL THREE ROBOT'S BEHAVIORS

occupation	# of respondents
interns	1
researchers	2
managers	1
clerical assistants	7

age	# of respondents
20s	3
30s	7
40s	2

A. Result of factor analysis and acceptance of robot

We have conducted a factor analysis to investigate what factors dominate the evaluation of the robot. Table III shows the result of factor analysis (principal factor method, equamax with Kaiser normalization) for the scores of adjective pairs. There is a possibility that the scores in the questionnaires are affected by factors which are not related to the behavior changes since the environment and respondents were not controlled in this study. Then, we decided to use the method that does not need to assume the number of factors beforehand and analyze factors that the cumulative proportions exceeds 70%. The cumulative proportion from first to fifth factors shown in Table III is 73%. We call the first factor *favorability* since the components of the first factor (factor load > 0.6) are "amusing", "cute", "likeable", and "not-obstructive". The second factor consists from "thoughtful," "robot is aware where it is," and "honest." We call it *circumstance-appropriateness (c-app.)*. We call the third factor *childishness* since it consists from "amiable" and "irresponsible", which are related to the child like behaviors of the robot. The fourth factor is named *social-role* since the factor loads of "diligent" and "earnest" are high. The factor loads of "lively" and "quiet" are high in fifth factor and we call it *activeness*.

The familiarity of the robot relates with the first factor *favorability* and the third factor *childishness*. The *childishness* evaluation comes from the robot's appearance, that is, its small height, child like behaviors, and child like voice, which is peculiar evaluation to the robot used in the study. Then we name the first factor *familiarity*.

We classified the respondents into three groups X, Y, and Z as in Fig. 2 according to their experiences.

X) respondents who frequently talked when they met the robot,
Y) respondents who rarely talked when they met the robot,
Z) respondents who rarely met the robot.

Fig. 8 shows the meeting ratio and interaction experience of the respondents.

Table IV shows the Pearson's coefficient correlation between the five factor scores and *acceptance* for three groups. From the table, we can see that there is no correlation between the fifth factor *activeness* and *acceptance* in all people. In group X, *familiarity* has strong positive correlation with *acceptance* (0.952, $p < 0.01$) and weak positive correlation between *c-app.* and *acceptance* (0.627, $p < 0.05$). This is due to the fact that the respondents in group X evaluate

TABLE III

FACTOR MATRIX GIVEN BY THE FACTOR ANALYSIS (PRINCIPAL FACTOR METHOD, EQUAMAX WITH KAISER NORMALIZATION)

factor matrix	1st	2nd	3rd	4th	5th
amusing	0.84	0.00	-0.18	0.26	-0.11
cute	0.82	0.00	0.07	-0.11	-0.06
likeable	0.78	0.05	0.29	0.32	-0.13
not-obstructive	0.71	0.45	0.16	-0.07	0.24
thoughtful	-0.11	0.84	-0.03	0.00	0.13
robot is aware where it is	0.44	0.70	0.24	-0.06	0.03
honest	0.10	0.67	-0.34	0.00	-0.18
amiable	0.23	0.14	0.85	0.11	0.03
responsible	-0.10	0.36	-0.83	0.15	-0.03
deligent	0.03	-0.02	0.03	0.90	0.12
earnest	0.35	-0.06	-0.02	0.73	-0.01
lively	0.14	0.07	0.25	0.22	0.83
quiet	0.32	0.03	0.21	0.08	-0.75
warm	0.57	-0.01	0.31	0.33	0.08
active	0.35	-0.46	0.07	-0.45	0.34
quick	0.18	0.48	-0.44	-0.09	0.38
cumulative proportion	22%	37%	50%	62%	73 %

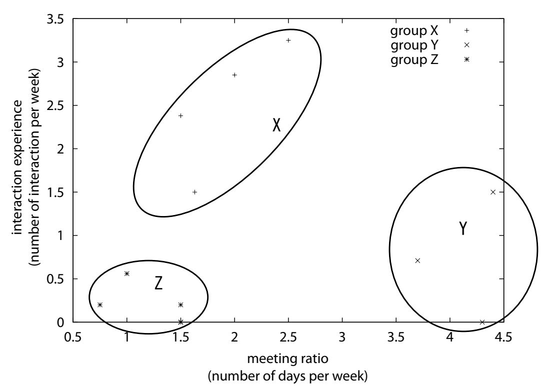

Fig. 8. This figure shows the distribution of meeting ratio (number of days that a respondents met the robot per week) and the interaction experience (the number of interaction that he/she had per week). In group Z, there were two subjects that both numbers are congruent.

the robot according to their own experiences. Thus, they evaluated the robot highly with *familiarity* according to their communication experience with the robot.

In group Y, *familiarity* and *c-app.* have strong positive correlation with *acceptance* (0.868, $p < 0.01$ and 0.850 $p < 0.01$ respectively). The *childishness* and *social-role* have positive correlation with *acceptance* (0.678, $p < 0.05$ and 0.719, $p < 0.05$ respectively). Respondents in group Y evaluate the robot mainly from their observation experiences, such as, watching the human-robot interaction of the group X and the robot, the robot's behavior when the robot went by, it tried to talk, it disturbed people, and so on, which relates to *circumstance-appropriateness*. Then their *acceptance* evaluation more correlated with the factor of *c-app.* compared to the group X. The low correlation between *social-role* and *acceptance* comes from the fact that they did not notice that it was playing a social role of a messenger. Then they did not change *acceptance* after the robot started the messenger task. There is weak correlation between *childishness* and

TABLE IV

PEARSON'S COEFFICIENT CORRELATION BETWEEN THE FIVE FACTORS AND THE ACCEPTANCE.

group	favorability (familiarity)	c-app.	childishness	play-social-role	active-ness
X	0.952 **	0.627*	0.485	0.489	-0.315
Y	0.868 **	0.850 **	0.678*	0.719*	-0.156
Z	0.241	0.204	0.333	0.262	0.460

* significant in $p < 0.05$, ** significant in $p < 0.01$

acceptance. We do not discuss for this factor since it is peculiar factor for the robot as we noted before.

There are no correlations between five factors and *acceptance* in group Z. This is due to the fact that their evaluation had large variances in the group since they did not have chance to see the robot nor obtained enough hearsay knowledge in six weeks, which led to the evaluation were done by their initial knowledge.

From these results, we conclude that *acceptance* of group X and Y becomes high when they highly evaluate the robot's *familiarity*, *circumstance-appropriateness.*, and *social-role*. Also, the higher the group X and Y's *acceptance* is, the higher *acceptance* of group Z will be since they evaluate the robot by hearsay knowledge from people in groups X and Y.

B. Changes of acceptance

Comparing the average *acceptance* for the first and second weeks with the average of the fifth and sixth weeks, we found the following: 1) averaged *acceptance* was identical for the seven respondents, 2) *acceptance* increased for one respondent, 3) *acceptance* decreased for four respondents. And there were small changes in each factor score and *acceptance* evaluation within each respondent. From the free-answer questions in the questionnaire and the comments given to the experimenters, there seemed to be two main causes of the decrement of *acceptance*.

First, some did not like the *staying area*. Since the robot sometimes disturbed people by greeting them in the corridor in the previous study, it was programmed to only talk in the *staying area* from the 3rd week. Here, people make tea or coffee during breaks, where if they meet someone, they talk. We assumed that people would welcome conversation with the robot in that area. However, some respondents felt that this place was inappropriate for the robot to stay-and-talk since the area is rather small and the robot sometimes interfered with people preparing tea/coffee or opening the refrigerator. This explains some lowered *c-app.* and *acceptance* scores in the fifth and sixth weeks.

Second, the robot stopped talking in the corridor from the 3rd week after it started to remain in the *staying area*. Some people seemed to notice that the robot stopped talking to them when they met in the corridor and apparently they preferred being approached in the corridor, even though some thought it was annoying. Their impressions of the robot's *familiarity* and *acceptance* decreased.

The variances of *familiarity*, *c-app.*, and *social-role* within a respondent were 1.25 or below in six weeks. That means the impression of respondents did not change so much even when the robot stopped talking in the long corridor or start acting as a messenger. One of the reason is that most of the respondents did not have enough chance to see the robot as they only see the robot for once or twice in a week. Some noticed that the robot started to carry a pink bag and only one noticed that it started working from the utterance of the robot. They did not seem to notice that the robot was carrying a document in the bag and playing a messenger role.

C. Respondents' view of robot and acceptance

Table V shows how the twelve respondents regarded the robot over the six-week period. Respondents were allowed to mark more than one choice for a week. If a respondent marked the same choice for more than two weeks, it was counted as one. Table V shows that many respondents regarded the robot as a kind of "machine" rather than a kind of "creature," and there are large variants in their views. Table VI shows how the respondents changed their views in the "creature" and "machine" categories. From the table, we can see that the respondents did not drastically change their own views. Respondents are classified into four groups: C, N, M, and O. Groups C and M include those who tended to see the robot as a creature and a machine, respectively. Group N regarded the robot both as a creature and a machine throughout the six weeks. No respondents changed their view from "creature" to "machine" or vice versa over the six-week period. However, they would belong to Group O if they had.

Fig. 9 illustrates the differences of averaged *acceptance* between respondents in group C and others (groups N & M) throughout the study. Group C's average *acceptance* is higher than the other respondents (statistically significant in Mann-Whitney U-test, $p = 0.02$).

Fig. 10 illustrates the difference of the three evaluation indexes of the respondents in group C and groups N & M. The *familiarity* and c-app. of the group C were statistically higher than those of groups N & M (Mann-Whitney U-test, $p = 0.00$.) There were no significant difference in *social-role* ($p = 0.076$), in *childishness* ($p = 0.499$), and in *activeness* ($p = 0.499$). The result were consistent with the one when we conducted test excluding the respondents in people Z.

V. Discussion

What is the key issue for a robot to be socially accepted? Do we need to design a robot so that it looks like a creature? Most of the respondents who regarded the robot as a creature (group C) scored *acceptance* higher than respondents who regarded it as a machine (groups N and M). However, there were some respondents in groups N and M who gave higher *acceptance* than the value given by people in group C. Then, we argue that it is not the key issue but the three issues, *familiarity*, *circumstance-appropriateness*, and *social role*, are more important for a robot to obtain a higher *acceptance*. In the following, we will discuss the importance of the three issues from the view of personal and social acceptance.

TABLE V

Respondents' perceptions of robot after six weeks. They could mark more than two choices.

category	answer	# of respondents
creature	unfamiliar creature	4
	pet	6
	friend	2
	servant	1
	child	6
	adult	0
machine	toy	3
	machine	8
	AI	1
	automatic responding machine	3
	technical interests	2
	interest in conversation	0
	interest in robots	6
	other	1 (information source)

TABLE VI

Changes of respondents' views of robot

	first week's view	sixth week's view	# of respondents
C	creature	creature	1
	creature	creature & machine	1
	creature & machine	creature	1
N	creature & machine	creature & machine	2
M	creature & machine	machine	1
	machine	creature & machine	2
	machine	machine	4
O	creature	machine	0
	machine	creature	0

A. Personal acceptance of robots

Before discussing the social acceptance of robots, let us further explore their personal acceptance. In a year-long field study Forlizzi [3] compared the fanciest stick vacuum cleaner and "Roomba," a cleaning robot. Subjects were given either a lightweight, easy to use stick vacuum that they had to operate themselves or a cleaning robot that they could simply push start button and walked away; but later they had to complete the job using another vacuum since the cleaning robot's efforts are incomplete. She reported that subjects given the stick cleaner stopped using it before the

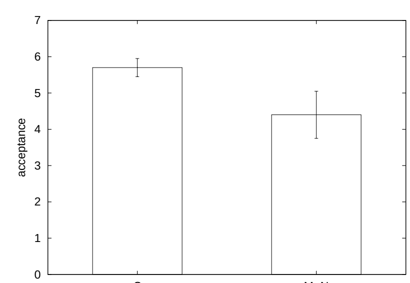

Fig. 9. Difference of average and deviations of *acceptance*'s between respondents in "C" group and "M" or "N" group. The averages are taken for six weeks. They have statistically significant differences (Mann-Whitney U-test, $p = 0.02$).

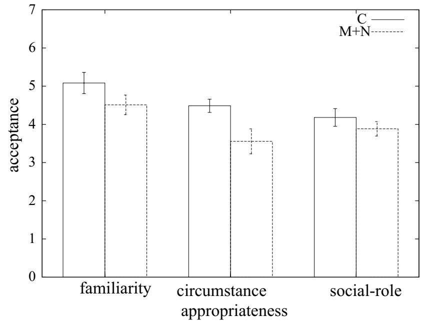

Fig. 10. Differences of averages and deviations of *familiarity*, *c-app.*, and *social-role* measures between respondents in group C and groups M & N. The averages are taken for six weeks. *Familiarity* and *c-app.* have statistically significant differences (Mann-Whitney U-test, $p = 0.00$).

year elapsed. However, subjects given the cleaning robot continued using it even after the one-year study period finished. We also note that more than two million "Roomba"s have been sold. Then, "Roomba" is one example of the robot that is personally accepted.

The autonomous task completion is the critical difference between a cleaning robot and a vacuum cleaner. You can do something else while the robot is cleaning, even though you need to do a little more work to finish the cleaning. Thus, in this example, the robot gains high evaluation in *social role* and accepted.

Another robot task that separates it from a machine is as a companion. Paro [9] is a well-known therapeutic robot. AIBO and Primopuel are commercial products targeted at those who want such companions. AIBO is a series of four-legged pet robots for amusement at home. Primopuel is a series of stuffed toy dolls that have sensors in them. They respond and change behaviors based on voice and tactile communication. Sony has sold more than 140,000 AIBOs, and BANDAI has sold more than a million Primopuels. Then, we can say that these companion robots, which rolls are communication, are accepted.

Then, we argue that a robot is accepted when it gives enough *familiarity* to the user and completes an expected *social role*. The user don't care for *circumstance-appropriateness* when a robot is used personally, since the user can turn it on and off as he/she likes.

B. Social acceptance of robots

Next question is whether a robot also is socially accepted when it offers *familiarity* and *plays a social role* as in the case of personal acceptance. Do all people in a society regard the robot has *familiarity* and *plays social role*?

In a community, there are many applications or social roles for a robot, including guide, receptionist, messenger, secretary and so on. For the people X who interact with it, the *familiarity* is important and its *social role* evaluation will increase if a robot plays one such role, as in the discussion of personal acceptance of the robot. Since the robot's target is people X, the robot's *familiarity* and *social role* are designed for them. Then there are cases that the design is not perfect for people Y and Z.

Meanwhile, we found that the correlation between *c-app.* and *acceptance* of people Y, who have less interaction with the robot, is higher than that of people X who interacts more frequently with the robot from the study. Note that some might not perceive that the robot is *playing a social role* even if they see that the robot is "working". Also, people Z, who do not directly contact with the robot, evaluate the robot from the hearsay from people X and Y. Then the acceptance of group Y dominate the social acceptance of the robot when a community grows since the number of people Y and Z increases at that time.

Then, we conclude that it is highly recommended to design a robot considering the *circumstance-appropriateness* in addition to the *familiarity* and the *social role* for the main users.

VI. Conclusion

A robot in a community is evaluated by three criteria: 1) *familiarity*, 2) *circumstance-appropriateness*, and 3) *social role*. We showed the positive relationships between those three evaluations and *acceptance* by individuals in a community in a six-week study. In the discussion, we argued that improving *circumstance-appropriateness* is the most important issue for a robot to gain social acceptance. Determining appropriate behavior for a robot in various circumstances is the next open question.

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