Questionnaire–Based Research on Opinions of Visitors for Communication Robots at an Exhibition in Japan

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Abstract. This paper reports the results of questionnaire–based research conducted at an exhibition of interactive humanoid robots that was held in the Osaka Science Museum, Japan. The aim of this exhibition was to investigate the feasibility of communication robots connected to a ubiquitous sensor network, under the assumption that these robots will be practically used in daily life in the not–so–distant future. More than ninety thousand people visited the exhibition. An questionnaire was administrated to the visitors to explore their opinions of the robots. Statistical analysis was done on the data of 2,301 respondents. It was found that the visitors' opinions varied according to age; younger visitors did not necessarily like the robots more than elder visitors; positive evaluation of the robots did not necessarily conflict with negative evaluations such as anxiety; there was no gender difference; and there was almost no correlation between the opinions and the length of time spent near the robots.

1 Introduction

The aim of communication robots is to act in environments with humans and assist humans through communication with them. Humanoid–type robots are considered to be useful in this communication task, for example, by gesturing with their faces, arms, and eyes in guidance tasks for maps.

One realization method for communication robots is ubiquitous computing, where robots use information from sensors, not only in the robots themselves but also in the environments in which they exist [1–3]. This method assumes that all the objects in the environments have their own IDs by using wireless tag systems [4–6]. The most important characteristic of this method is reduced computational cost in the identification of environments by robots, which is difficult in cases where each robot must act alone. Moreover, guidance of the contents of museums is considered to be an effective application of communication robots using these ubiquitous sensor networks. Although there is an application research for this task for one robot, it focuses on providing information by the robot [7]. From the perspective of communication robots, the interaction between robots and humans via the sensor network information is more important.

To investigate the effectiveness of communication robots connected through ubiquitous sensor networks in guidance tasks, an exhibition of humanoid robots, called "Robovie" [8], was held at the Osaka Science Museum [4], Japan, for approximately two months in 2004. At this exhibition, a questionnaire was distributed to visitors to explore their opinions of the robots.

Although there has been some existing research on psychological evaluations of visitors of robots at science museums [9–11], these studies have been limited to individual impressions of specific robots behaving alone. The Osaka Science Museum exhibition focuses on interaction between visitors and robots via sensor network information in a guidance task. Thus, the visitors' opinions of the robots are considered to reflect impressions of this interaction. In particular, the research evaluates not only opinions of interest in, friendliness toward, and effectiveness of the robots, but also anxiety toward them. In addition, it focuses on relations among these psychological features, concrete behavior such as time spent near the robots, and personal traits such as gender and age. Anxiety toward robots and its relation to behaviors and personal traits are important factors to be investigated when communication robots behave in environments with humans and communicate with them [12].

This paper sets forth an overview of the communication robot exhibition and then analyzes the results of the questionnaire data assembled at the exhibition.

2 The Communication Robots Exhibition

This section shows an overview of the ubiquitous sensor network, the communication robots, the procedures, and the questionnaire used at the communication robots exhibition.

2.1 Overview of Systems

The ubiquitous sensor network was constructed on the 4th floor of the Osaka Science Museum (see Fig. 1). This sensor network records visitor behaviors. This information was used by the robots to assist visitors viewing exhibits at the museum and encourage their interests in science and technology.

Sensor Systems: In this exhibition, visitors had wireless tags. Signals from these tags were detected by using a total of 20 wireless tag readers. The tag reader can detect signals from tags within a maximum of 10 m. The combination of strength of signals detected by several tag readers makes it possible to determine the physical positions of tags. Eighteen wireless tag readers were hung on the

[4] http://www.sci-museum.kita.osaka.jp/

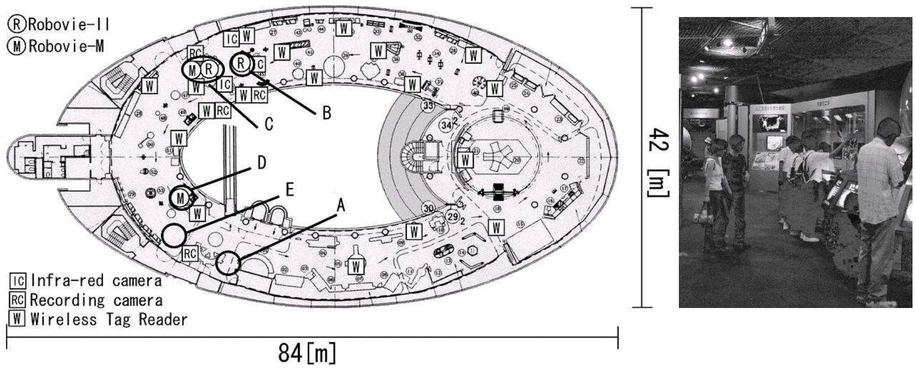


Fig. 1. Overview of the Osaka Science Museum and a Visitor Scene

ceilings near exhibits to detect whether visitors stayed near the exhibits. Two tag readers were inserted into the robots.

In addition, three infrared cameras were assigned to detect positions of the robots and four digital cameras were assigned to record scenes at the exhibition. All the cameras and tag readers, except for the ones assigned to the robots, were connected with corresponding PCs to control information maintenance in a database processed on a central server via ethernet.

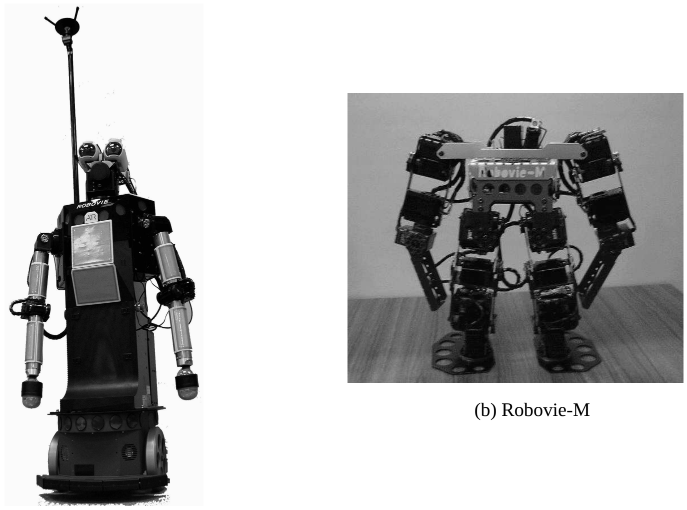
Robots: In the exhibition, two types of communication robots were used. Fig. 2 shows the humanoid robot, "Robovie" [8].

"Robovie–II", shown in Fig. 2(a), is a human–size robot that stands 120 cm tall. Its diameter is 40 cm, and it weighs about 40 kg. The robot has two arms (4×2 DOF (degrees of freedom)), a head (3 DOF), two eyes (2×2 DOF for gaze control), and a mobile platform (two driving wheels and one free wheel). This robot has various sensors, including skin sensors covering the whole body, 10 tactile sensors located around the mobile platform, an omni–directional vision sensor, two microphones to listen to human voices, and 24 ultra–sonic sensors for detecting obstacles. It carries a Pentium III PC on board for processing sensory data and generating gestures including utterance. Moreover, it is assigned one wireless tag reader.

"Robovie–M", shown in Fig. 2(b), is a small– size robot that stands 29 cm tall. It has 22 DOF, which makes it possible to execute various gestures such as walking, bowing, and a handstand (see
`http://www.vstone.co.jp/top/p_info/robot/robovie-m.html`).
Since the robot does not have its own function of utterance, its utterance is performed by the corresponding PC.

2.2 Procedures

Flow of Visitors: Visitors at the exhibition behaved as follows.



(a) Robovie-II

(b) Robovie-M

Fig. 2. Two Types of Robots Used in the Exhibition ((a): a human–size robot "Robovie–II", (b): a small–size robot "Robovie–M")

First, visitors register for their wireless tags at the reception desk at the entrance to the 4th floor (position A in Fig. 1). At this stage, their names, ages, and birthdays are registered and assigned to the tag IDs provided to them. Then, the registered names are automatically transfered into speech information that the robots use for their utterances to visitors.

Visitors are then free to see exhibits in the museum. All the wireless tag information is recorded in the database. While viewing the exhibits, visitors interact with a total of four robots, each of which has its own role. One provides guidance on the exhibits while moving alone. Two of them communicate with each other to provide guidance on the exhibits (position C in Fig. 1). Another robot executes interaction behaviors, such as calling visitors' names near the exit (position D in Fig. 1).

When visitors finish viewing the exhibits, they are asked to respond to a questionnaire on their opinions of the robots and the exhibition at the exit (position E in Fig. 1). Their responses are arbitrary. Wireless tags are then returned.

Roles of the Robots: At the exhibition, two Robovie–IIs and two Robovie–Ms were used.

One Robovie–II executed exhibit guidance in the museum while moving about (Fig. 3(a)). It explained the contents of exhibits, such as their history.

Another Robovie–II and one Robovie–M executed exhibit guidance while simulating interaction between them by synchronization via network (Fig. 3(b)).

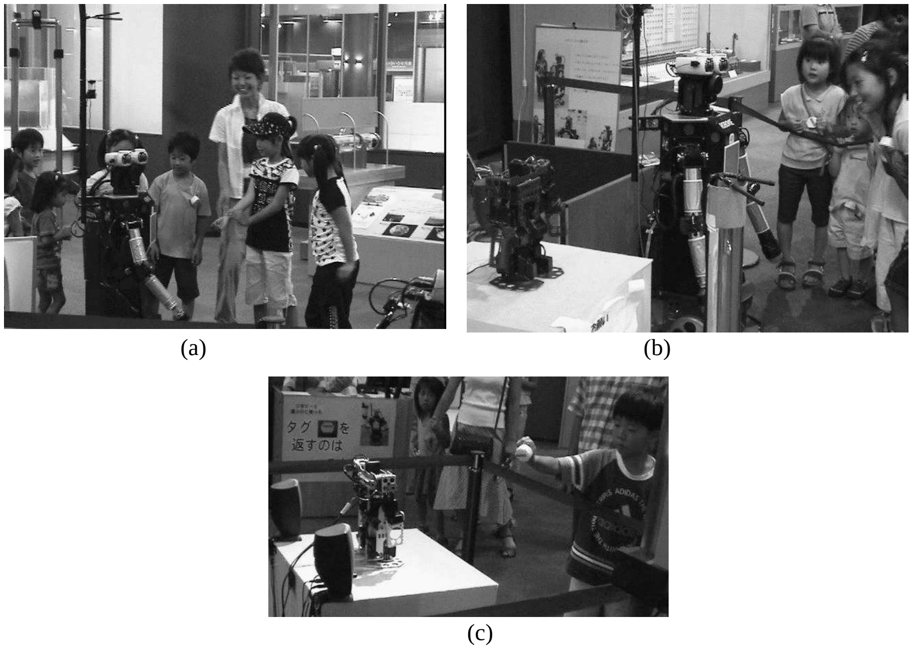


Fig. 3. Scenes of Interaction between the Robots and Visitors ((a): Guidance by Robovie–II, (b): Interaction between Robovie–II and Robovie–M, (c): Interaction with Robovie–M near the Exit)

In more detail, the Robovie–M explained an exhibit, the Robovie–II asked questions about it, and the Robovie–M then responded to the question. Moreover, these robots interacted with visitors by using information from the ubiquitous sensor network.

Remaining Robovie–M did not provide guidance, but instead interacted with visitors by calling their names based on visitor tags and registered information, saying good–bye, asking visitors to return their tags, and so on (Fig. 3(c)).

Questionnaire Items: The questionnaire used in the exhibition consisted of the following statements. Respondents indicate the degree to which each statement applies to them by marking whether they (1) "strongly agree", (2) "agree", (3) "are undecided", (4) "disagree", or (5) "strongly disagree".

Item 1 (Interest):
I am interested in the robots.
Item 2 (Friendliness):
I felt friendly toward the robots when I faced them.
Item 3 (Effectiveness):
I find guidance provided by the robots effective.

Item 4 (Anxiety toward Interaction):
I felt anxiety when the robots talked to me.
Item 5 (Anxiety toward Social Influence):
I feel anxiety about the possible spread of robots to perform tasks such as those shown at the exhibition in the near future.

The 1st, 2nd, and 3rd items measure respondents' interest in the robots, friendliness toward the robots, and evaluation of the robots' effectiveness, respectively. The 4th and 5th items measure the respondents' anxiety toward interaction with the robots and the social influence of the robots, respectively.

The questionnaire also includes items on gender and age. The item on age has seven graded answers (from for respondents in their 10's to 70's). In addition, the questionnaire has an item for freely describing opinions about the robots and the exhibition.

3 Analysis of the Data

The communication robots exhibition was held at the Osaka Science Museum, Japan, from July to August, 2004. This period included the Japanese summer holiday. By the end of the two–month period, the number of visitors reached 91,107 and the number of visitors who wore wireless tags was 11,927.

The total number of returned questionnaires was 3,034, the number of those not lacking either of the five items shown in section 2.2 was 2,891, and the number of those not lacking either the gender item or the age item was 2,301. Analysis considering factors of age and gender was executed for these 2,301 samples. Moreover, the number of questionnaires that included freely described opinions about the robots and the exhibition was 293.

Answers were scored in reverse order from 1 ("strongly disagree") to 5 ("strongly agree).

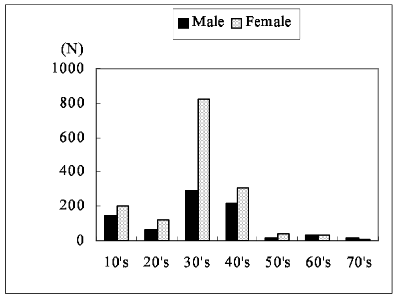
Moreover, the following information was measured as a behavior index, based on tag information from the ubiquitous sensor network:

T3: Time that visitors stayed within 3m of the point where Robovie–II and Robovie–M simulated their communication.

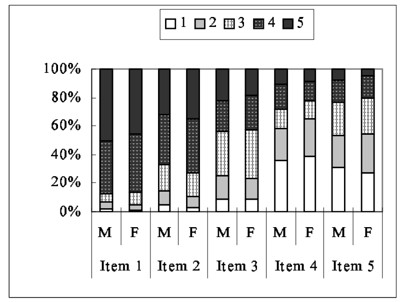
Analysis of the relation between this behavior index and the item scores was also executed.

3.1 Item Scores

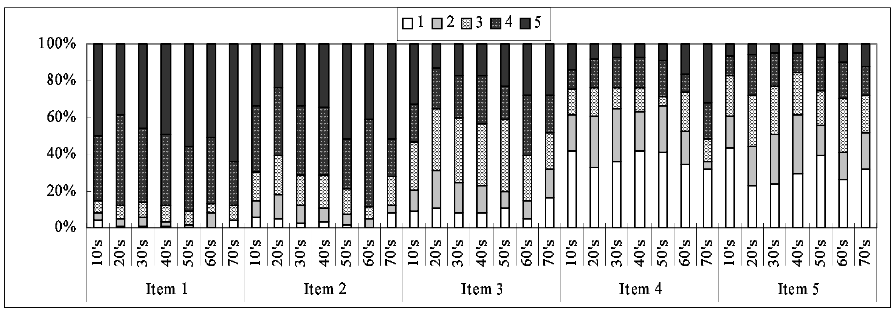
The number of male respondents was 777 and that of female respondents was 1,524. Moreover, the number of respondents aged in the 10's was 349, that in the 20's was 182, that in the 30's was 1109, that in the 40's was 519, that in the 50's was 56, that in the 60's was 61, and that in the 70's was 25. Fig. 4(a) shows the distribution of respondents based on gender and age. This figure indicates that there was a bias among respondents aged aged in their 30's and 40's, in particular, females in their 30's.



(a)



(b)



(c)

Fig. 4. Distributions of Respondents and Item Scores ((a): Distribution of the Respondents based on Gender and Age, (b): Distribution of Item Scores based on Gender, (c): Distribution of Item Scores based on Age)

Fig. 4(b) and (c) show the distributions of the item scores based on gender and age, respectively. These figures show that the rates of respondents scoring more than 4 on items 1 and 2 were more than 80% and about 70%, respectively. Moreover, the rates of the respondents scoring less than 2 on items 4 and 5 were about 60%. On the other hand, these figures imply that the distributions of the item scores may differ between ages.

Table 1 shows mean scores and standard deviations of the items based on gender and age, and the results of a two–way ANOVA for the item scores with factors of gender and age. There were statistically significant differences on items 2, 3, and 5 between ages. There was no statistically significant difference between genders. A Tukey post–hoc test found the following facts:

- The scores of item 2 in the 20's group were lower than those in the 30's, 40's, 50's and 60's groups.
- The scores of item 3 in the 20's group were lower than those in the 10's and 60's groups. Moreover, those in the 10's group were higher than those in the 30's and 40's groups.

– The scores of item 5 in the 10's group were lower than those in the 20's, 60's, and 70's groups. Moreover, those in the 40's group were lower than those in the 20's and 30's groups.

Table 1. Mean Scores and Standard Deviations of Items based on Gender and Age, and Results of Two–Way ANOVA for the Item Scores

			Item 1	Item 2	Item 3	Item 4	Item 5
10's	Male	Mean	4.319	3.882	3.708	2.424	2.243
	(N=144)	SD	0.944	1.087	1.300	1.508	1.360
	Female	Mean	4.171	3.790	3.468	2.307	2.166
	(N=205)	SD	1.064	1.192	1.282	1.434	1.225
20's	Male	Mean	4.203	3.531	3.016	2.313	2.828
	(N=64)	SD	0.858	1.221	1.315	1.296	1.352
	Female	Mean	4.212	3.653	3.093	2.415	2.559
	(N=118)	SD	0.772	1.081	1.094	1.316	1.121
30's	Male	Mean	4.300	3.746	3.174	2.436	2.582
	(N=287)	SD	0.950	1.174	1.182	1.362	1.273
	Female	Mean	4.245	3.960	3.265	2.270	2.519
	(N=822)	SD	0.837	1.002	1.159	1.289	1.150
40's	Male	Mean	4.256	3.786	3.284	2.414	2.335
	(N=215)	SD	0.914	1.077	1.215	1.340	1.152
	Female	Mean	4.372	4.010	3.309	2.141	2.263
	(N=304)	SD	0.729	1.013	1.127	1.334	1.142
50's	Male	Mean	4.368	4.105	3.105	2.316	2.000
	(N=19)	SD	0.684	0.875	1.100	1.416	1.155
	Female	Mean	4.486	4.270	3.459	2.297	2.568
	(N=37)	SD	0.731	1.071	1.304	1.431	1.425
60's	Male	Mean	4.484	4.290	3.710	2.645	2.548
	(N=31)	SD	0.677	0.864	1.131	1.518	1.312
	Female	Mean	4.100	4.200	3.667	2.467	2.900
	(N=30)	SD	1.062	0.714	1.155	1.432	1.322
70's	Male	Mean	4.294	3.941	3.353	3.235	3.000
	(N=17)	SD	1.047	1.345	1.412	1.786	1.458
	Female	Mean	4.750	4.250	3.125	3.000	1.625
	(N=8)	SD	0.707	1.165	1.642	1.604	0.744
F–Values	Gender		0.043	1.689	0.003	1.132	1.609
	Age		0.937	4.186	6.223	1.665	6.514
	Interaction		1.642	1.109	1.027	0.448	2.165
p–Values	Gender		0.836	0.194	0.959	0.287	0.205
	Age		0.467	0.000	0.000	0.126	0.000
	Interaction		0.132	0.355	0.406	0.847	0.044

3.2 Time that Respondents Stayed Near the Robots

The behavior index T3 may reflect the respondents' interest, friendliness, and anxiety toward the robots to some extent. However, it can be influenced by external factors, such as congestion on the floor. In fact, the number of visitors per day was widely distributed during the period (the maximum: 3,240, the minimum: 767, the average: 1,898, the median: 1,780), due to the fact that this period included the Japanese summer holiday. Thus, the days that more than 2,250 people visited, including the summer holiday, were assumed to be congested days and the effect of congestion on the behavior index was analyzed.

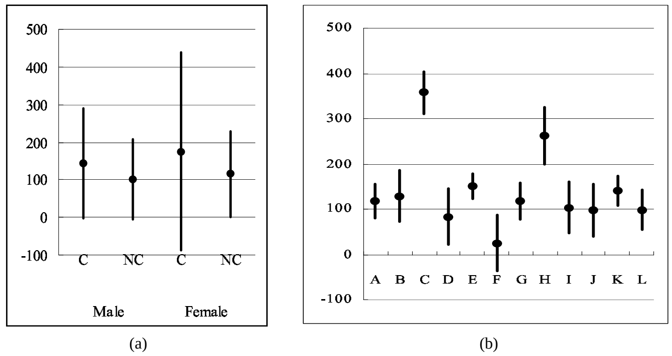


Fig. 5. Mean Values and Standard Deviations of T3. (a): on Gender and Congestion Condition (C: Congestion, NC: Non–Congestion, Male–C: $N = 414$, Male–NC: $N = 363$, Female–C: $N = 699$, Female–NC: $N = 825$). (b) on Categories of Freely Described Opinions (A: $N = 14$, B: $N = 6$, C: $N = 9$, D: $N = 5$, E: $N = 26$, F: $N = 5$, G: $N = 12$, H: $N = 5$, I: $N = 6$, J: $N = 6$, K: $N = 18$, L: $N = 10$)

Table 2. Peason's Correlation Coefficients r between the Item Scores and Behavior Index T3

	Item 1	Item 2	Item 3	Item 4	Item 5	T3
Item 1	–	0.521	0.385	-0.095	-0.123	0.077
Item 2	0.521	–	0.459	-0.142	-0.128	0.059
Item 3	0.385	0.459	–	-0.030	-0.100	0.036
Item 4	-0.095	-0.142	-0.030	–	0.372	0.048
Item 5	-0.123	-0.128	-0.100	0.372	–	-0.018

First, a two–way ANOVA with factors of the congestion condition and age was executed. Only the congestion condition had an effect (age: $F = 1.186$, $p = 0.083$, congestion: $F = 20.406$, $p = 0.000$, interaction: $F = 0.885$, $p = 0.505$).

Next, a two–way ANOVA with factors of the congestion condition and gender was executed. Both the congestion condition and gender had an effect (gender: $F = 8.111$, $p = 0.004$, congestion: $F = 44.930$, $p = 0.000$, interaction: $F = 1.171$, $p = 0.279$). Fig. 5(a) shows the mean values and standard deviations of T3 on the genders and congestion conditions. It was found that the T3 values of the visitors on congested days were about 50 sec larger than those on non–congested days, and the T3 values of the female respondents were more than 10 sec larger than those of the male visitors.

3.3 Correlations between the Item Scores and Behavior Index

Table 2 shows Peason's correlation coefficients r between the item scores and behavior index T3. There were medium level correlations between items 1–3, and between items 4–5. On the other hand, there were little correlations or low level correlations between the group of items 1–3 and that of items 4–5.

Table 3. Categories of Freely Described Opinions of the Robots and Exhibition, the Number of Opinions Classified into Each Category, and Examples of Opinions Classified into Each Category

Category	*N*
A. Positive Opinions of the Robots Themselves (Example: "I was grad to be talked by the robots.")	23
B. Expectations for Robots and Technology in the Future (Example: "I will be enjoyable if there are more kinds of robots."),	16
C. Positive Attitudes of Children toward the Robots (Example: "My child seemed to be glad to be called by the robots.")	17
D. Desires on Interaction or Touch with the Robots (Example: "I wanted to talk with the robots more.")	8
E. Negative Opinions of Communication with the Robots (Example: "The robots' utterances were hard to listen.")	59
F. Negative Emotions toward the Robots (Example: "I felt a little fear toward the robots.")	10
G. Fear of Children toward the Robots (Example: "My child seemed to feel fear toward the robots.")	20
H. Children's Indifference to or Non–Interest in the Robots (Example: "My child seemed to lose interest with the robots, because they did not react to the tag of the name.")	9
I. Other Dissatisfaction with the Robots (Example: "The robots' reaction was slower than that I expected.")	12
J. Physical Danger in Interaction with the Robots (Example: "The robot's arm stroke my child.")	7
K. Positive Evaluation of the Exhibition ("I was happy because I could directly come in contact with the robots.")	27
L. Critical Requests for the Contents of the Exhibition (Example: "Please prepare more kinds of robots.")	17
O. Other 4 Categories	68

Moreover, there were little correlations between the item scores and behavior index T3.

3.4 Freely Described Opinions

A total of 293 sentences of opinions of the robots and exhibition were manually classified into several categories based on similarity between the contents of the sentences. This classification was executed by two people, discussing the contents of the sentences and categories until their classification results became equal. Finally, 16 categories were extracted and each sentence was classified into one of them. Table 3 shows these categories, the number of sentences classified into each category, and examples of the sentences classified into each category.

Categories A–D were positive opinions of the robots themselves. A corresponds to sentences expressing positive opinions and emotions toward the robots' appearance, interaction, intelligence, and so on. B corresponds to sentences expressing expectations and positive requests for robots and technology in the future. C corresponds to sentences expressing positive attitudes of children toward robots, described by the children themselves or their parents. D corresponds to sentences such as “I wanted to interact with the robots more”.

Categories E–J were negative opinions of robots themselves. E corresponds to sentences expressing dissatisfaction with and negative opinions of the robots' functions of utterance, recognition, communication, and so on. F corresponds to sentences expressing negative emotions toward robots, such as anxiety, fear, compassion, and so on. G corresponds to sentences stating that children felt fear or anxiety toward the robots, as written by the children themselves or their parents. H corresponds to sentences indicating that children were indifferent to or had no interest in the robots, as written by the children themselves or their parents. I corresponds to sentences expressing other dissatisfaction with the robots. J corresponds to sentences about physical danger in interaction with the robots, such as the fact that a robot's arm struck at the visitor's body.

Categories K and L were evaluation opinions of the exhibition. K corresponds to a positive evaluation, such as “I would like to visit here again”. L corresponds to critical requests for the contents of the exhibition, such as types of robots to be exhibited. The other four categories correspond to sentences on dissatisfaction with external factors not related to the robots and content of the exhibition, such as congestion of the floor and waiting time for demonstrations. Thus, these four categories were reduced on analysis.

Respondents of categories A–D and K were grouped as those having positive opinions, and respondents of categories E–J and L as those having negative opinions. The number of positive opinions and that of negative opinions were 91 (31%) and 134 (45.7%), respectively. The opinions classified into A and K dominated more than half of the positive opinions. Moreover, category E had the largest number of opinions among the negative opinions and dominated 44% of the negative opinions.

In order to investigate the relation between these opinions and the time that the respondents stayed near the robots, a one–way ANOVA with the opinion categories was executed for the behavior index T3. Since the external factor of congestion may influence the analysis, as mentioned in section 3.2, this ANOVA was limited to the respondents on the non–congested days. Fig. 5(b) shows the mean values and standard deviations of T3 on the categories. As a result, there was a statistically significant effect of the categories ($F = 2.930$, $p = 0.002$). A Tukey post–hoc test found that the T3 values of the respondents classified into C were larger than those in all the other categories except for H.

3.5 Discussion

Influence of Age: The results in section 3.1 show that many visitors positively evaluated the robots. In more detail, many visitors had interest in and felt friendliness toward the robots. Moreover, many visitors did not feel anxiety about interaction with the robots and their social influence.

On the other hand, there were differences on these opinions between ages. The results show that people in their 20's feel less friendliness toward robots than those in their 30's – 60's, people in their 20's less positively evaluate guidance by the robots than those in their 10's and 60's, people in their 10's more positively evaluate the guidance than those in their 30's and 40's, people in their 10's feel less anxiety about social influence of the robots than those in their 20's, 60's, and 70's, and people in their 40's feel less anxiety about the social influence than those in their 20's and 30's. In other words, younger ages do not necessarily like the robots more than elder ages. An implication from the above results is that the design of robots should be changed according to ages.

Relations to Behaviors: The results in section 3.2 show that some external factors influence concrete behaviors in real situations, such as museums. However, the results in section 3.3 show that there is no relation between opinions of the robots and the concrete behavior of staying near the robots. An implication from these results is that environmental factors more strongly may affect behaviors than psychogical factors in real situations such as museums.

Moreover, the results in section 3.3 also show that interest in, friendliness toward, and evaluation of effectiveness of the robots do not necessarily conflict with anxiety toward them. They imply that degigns of robots for their effectiveness and friendliness do not necessarily reduce anxiety toward them.

Attitudes of Children towards Robots: The results in section 3.4 indicate that there are both positive and negative opinions of the robots and the exhibitions on a concrete level. They also show that there exist several dissatisfactions with the functions of the communication robots, and people, in particular, children, may have negative emotions toward the robots at the current level. On the other hand, they show that there are children who had interest in and friendliness toward the robots, and indicate that these children and their parents stay near the robots longer than others.

The above results can be interpreted as follows. In Japan, there are several types of discourses on robots and that naturally differs on between age groups. The results in section 3.1 reflect this. Moreover, many children have never seen actual moving robots, although they are affected by several media. This gap may lead to the fear and anxiety toward the robots shown in section 3.4. If this interpretation is valid, it concludes that design of robots for children should be suitable for the existing image of robots presented in several media.

Gender Difference: The results in section 3.2 reveal a tendency for females to remain near the robots longer than males. However, there is some doubt as to whether there is a gender difference in behavior toward the robots, as shown in section 3.2, at least in the situation presented in this research. In fact, there was no gender difference in opinions shown in the items, and no correlation between them and the behavior index.

As a cause, it can be surmised that many of the visitors were females in their 30's and 40's, The period included the summer holiday and, as a result, many females visited the exhibition with their children. In other words, it can be assumed that their children stayed near the robots longer with them and, as a result, the females appeared to be staying longer. This assumption needs to be investigated through another type of data, such as orbits in which the visitors moved while viewing the exhibits. This data will be analyzed in future research.

4 Summary

This paper reported the result of questionnaire–based research conducted at an exhibition of interactive humanoid robots that was held at the Osaka Science Museum, Japan, for the aim of investigating the use of communication robots connected with a ubiquitous sensor network. More than ninety thousand people visited the exhibition and a questionnaire was administered to the visitors for the aim of exploring opinions of the robots. Statistical analysis was done for data consisting of 2,301 respondents. It was found that the visitors' opinions of the robots differed according to age, younger ages did not necessarily like the robots more than elder ages, positive evaluation of the robots did not necessarily conflict with negative evaluations such as anxiety, there was no gender difference in opinions of the robots, and there was almost no correlation between the opinions and the length of time spent near the robots.

As future research, the relations between the visitors' opinions of the robots and another behavior index should be explored. Moreover, there was a bias of respondents in assembling samples. Although this bias may not be able to be avoided in situations such as museums, data from various types of people needs to be assembled.

Acknowledgments

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