How does appearance of agents affect how people interpret the agents' attitudes – Experimental investigation on expressing the same information from agents having different appearance

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***Abstract*— An experimental investigation of how the appearance of agents affects interpretations people make of the agents' attitudes is described. We conducted a psychological experiment where participants were presented artificial sounds that can make people estimate specific agents' primitive attitudes from three kinds of agents, e.g., Mindstorms robot, AIBO robot, and a normal laptop PC. Specifically, the participants were asked to select the appropriate attitude based on the sounds expressed by these three agents. The results showed that the participants had higher correct interpretation rates when a PC presented the sounds, while they had lower rates when Mindstorms and AIBO robots presented the sounds, even though these agents expressed information that was completely the same.**

I. Introduction

Recently, one of the hottest topics in human-computer interaction or human-agent interaction studies is "how does appearance of agents affect their interactions with people." People are said to determine agents' behavior models based on the appearance of the agents so that the agents' appearance significantly affects their way of interactions [1]. For example, when people encounter a dog-like robot, they expect dog-like behaviors from this robot, and they would naturally speak to it using commands and other utterances intended for dogs, such as "sit", "lie down", and "fetch." However, they do not act this way toward a cat-like robot.

Several studies have focused on the effects of appearance of agents on interactions with people [2,3,4]. For example, Kiesler et al. [2] conducted a psychological experiment where participants were asked to play a prisoner's dilemma game with virtual characters (human and dog) that appeared on a computer display. The results showed that participants who had some experiences with owing dogs interacted significantly more effectively with the dog-like virtual agent, e.g., cooperating with this agent significantly. Goetz et al. [4] investigated the effects on people's impressions of different designs of the head for humanoid robots. The results showed that the participants answered that the robots with human-like heads are good at social tasks, while robots with machine-like heads are good at industrial tasks. It can be said that these were pioneering studies concerning about the effects of appearance of agents on people's impressions.

On the basis of the findings of these studies, we focused on the issue how people interpreted the expressed information from agents having different appearances, especially just after these people have determined the agents' behavior models based on their appearances. Simply stated, we focused on the relationship between the agents' appearances and their expressed information. As already mentioned in the above, when people are face to certain agents, they determine the agents' behavior models. They would then interpret the agents' expressed information according to this agents' behavior model, and would start interacting with this agent. Therefore, this study constitutes a significant step toward clarifications of the issue "how does appearance of agents affect their interaction with people." Moreover, the result of this study would contribute to a design policy of the agents, such as "what kind of appearance should agents have in order to interact with people effectively, and which kinds of information should these agents express to people?"

II. Related studies

Several approaches can be used to tackle with the issue about the relationship between the agents' appearance and their expressed information. For example, Matsumoto et al. [5] proposed "Minimal Design" for designing the interactive agents; that is, agents should only have minimum amounts of appearance for users. In fact, they applied this minimal design policy for developing their interactive robot "Muu" [6] and life-like agent "Talking Eye" [7]. Although it can be said that this study focused on the effects of appearance of agents on people's impressions which is the same as the Kiesler's study [2] in the above, this study did not mention about the relationship between the agents' appearances and their expressed information; otherwise, this study proposed a rather abstract design strategy of the interactive agents.

Reeves and Nass showed in their "Media Equation" [8] studies that anthropomorphized agents or computers might induce humans' natural behaviors, like behaving toward humans. It is said that their studies focused on people's characteristics in which people generally anthropomorphize artifacts, even though these artifacts do not have human-like appearances, so that these studies are not about the relationship between the appearance and the expressed information.

Kanda el al. [9] conducted psychological experiments to observe peoples' behaviors toward two different types of humanoid robots ASIMO (Honda Motor Co., Ltd.) and

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Robovie (ATR-IRC). The results of this study showed that the different appearance of these two robots affected the people's nonverbal expressions, such as gestures and body movements. However, this study also did not mention about the relationship between the appearance and the expressed information.

III. Agents' attitudes, appearance, and expressed information

Specifically, we conducted a simple psychological experiment to investigate how people interpret presented artificial sounds as expressed information to see if they could determine specific attitudes from agents that have different appearance, in order to clarify the relationship between the agents' appearance and their expressed information.

We actually selected positive and negative attitudes corresponding to valence values [8] as the primitive attitudes that the agents should express. Informing people of these two primitive attitudes is quite important if the agents are to interact effectively with people [10].

Next, the artificial sounds that do not include any verbal information but are simple and intuitive information for people were presented to inform people certain agents' primitive attitudes. Komatsu [11] showed that people can estimate different primitive attitudes by means of simple beep-like sounds with different duration and inflections. These simple but intuitive expressions are called as subtle expressions [12]. Based on the results of this Komatsu's study, we speculated that agents with life-like appearances expressing true-to-life information are sometime more confusing to users and are not really effective for interacting with people; Instead, there are a lot of cases that agents without such life-like appearance expressing subtle expressions are readily understood and are much more effective [13,14]. So this is the reason why we utilized such subtle expressions.

We then selected three artifacts for agents having different appearance: a Mindstorms robot (The LEGO group), AIBO robot (Sony Corporation), and a normal laptop PC (Let's note W2, product of Panasonic Inc.). These artifacts correspond to making mechanical impressions of people, familial impressions, and non-agent-like impressions, respectively.

As a concrete procedure of this study, at first, we investigated the specific artificial sounds that could make people evoke positive or negative attitudes (preliminary experiment). We then conducted a psychological experiment to present the selected artificial sounds in the above preliminary experiment from the three different agents and to investigate how people interpreted the presented sounds. Finally, we summed up the results and discussed about the effects of agents' appearance on people's interpretation of the agents' expressed information.

IV. Preliminary experiment

Before the actual experiment, we conducted a preliminary experiment to determine what kinds of artificial sounds as subtle expressions are effective to evoke certain attitudes, positive or negative, from people. In this experiment, we focused on artificial sounds that acted as subtle expressions in the previous study [11]. We then investigated what kinds of sounds were interpreted as being positive or negative attitudes.

We prepared 44 difference types of triangle wave sounds with four different durations and 11 different F0 (fundamental frequency) contours. Specifically, the four durations were 189, 418, 639, and 868 ms. The 11 F0 contours were set so that the transition range of F0 values between the onset and endpoint in the sound stimuli were -125, -100, -75, -50, -25, -, 25, 50, 75, 100, and 125 Hz, and these were linearly downward or upward (Fig. 1). All these 44 stimuli had the same F0 average of 131 Hz and the same sound pressure (around the participants' heads: 60 dB (FAST, A)). In addition, these sounds had a tone that sounds like a computer's beeping. Actually, these sounds were presented by a normal laptop PC (Lets' note W2, product of Panasonic Inc.).

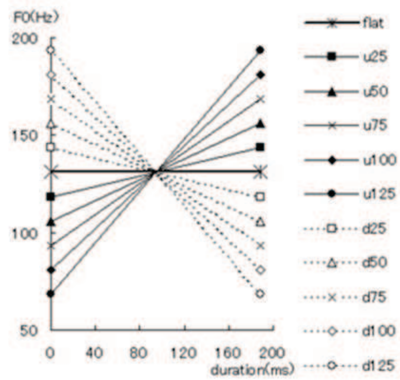

Fig. 1. 11 different F0 contours (duration: 189 ms). For example, "189u25" indicates that duration was 189 ms, and F0 transition rage was 25 Hz with upward slope (increasing intonation).

A. *Participants*

Ten Japanese university students (6 men and 4 women; 19-23 years old) participated. Hearing tests established that none of them had any hearing problems.

B. *Procedure*

Firstly, an experimenter gave the instruction, like "Please determine the attitudes of this PC based on the presented sounds." Participants were then asked to select one of the three attitudes "positive," "negative," or "undistinguishable" after presenting one of 44 prepared sounds. These three attitudes were described to participants as follows:

- **Positive**: the PC's internal state appears to be good.
- **Negative**: the PC's internal state appears to be bad.
- **Undistinguishable**: it is unclear whether the PC's internal state is positive or negative.

As a part of procedure, one randomly selected sound among 44 prepared sounds was presented to participants. Afterwards, the participants were asked to select one of the three aforementioned attitudes. Each participant heard all 44 prepared sounds. The order of presenting sounds was counterbalanced for all 10 participants.

	Participants									
stimuli	A	B	C	D	E	F	G	H	I	J
189d025	−	−	*	−	−	*	−	−	−	−
189u025	+	*	−	*	−	*	−	+	−	+
189d050	−	+	*	−	−	−	−	−	*	−
189u050	*	*	+	−	+	+	+	+	−	+
189d075	−	*	−	−	−	+	−	−	−	−
189u075	+	+	+	+	−	+	+	+	−	+
189d100	+	*	−	−	−	−	−	*	*	−
189u100	+	+	+	+	−	−	+	+	*	+
189d125	−	*	+	−	−	−	−	−	−	−
189u125	+	+	+	+	+	+	+	+	+	+
189du0	*	−	−	−	−	*	−	−	−	−
418d025	−	−	−	−	−	−	−	−	−	−
418u025	*	*	*	+	−	*	*	+	−	−
418d050	−	−	−	−	−	−	−	−	−	−
418u050	+	+	+	+	−	+	*	*	+	+
418d075	−	−	−	−	−	−	−	−	−	−
418u075	+	+	+	−	−	+	+	+	−	*
418d100	+	−	−	−	−	−	−	−	−	−
418u100	+	+	+	+	+	+	−	+	+	+
418d125	−	−	−	−	−	−	−	−	−	−
418u125	+	+	+	+	+	+	+	+	+	+
418du0	*	−	−	−	−	*	−	−	−	−
639d025	−	*	−	−	−	−	−	−	−	−
639u025	*	*	+	+	+	*	+	+	+	−
639d050	−	−	−	−	−	−	−	−	−	−
639u050	+	*	+	−	−	+	+	+	+	+
639d075	−	−	−	−	−	−	−	−	−	−
639u075	+	+	+	+	+	+	+	+	+	*
639d100	−	+	−	−	−	−	−	−	+	−
639u100	+	+	+	+	+	+	+	+	+	+
639d125	−	*	−	−	−	−	−	−	+	−
639u125	+	+	+	+	+	+	+	+	+	+
639du0	*	−	−	−	−	*	*	−	−	−
868d025	−	*	−	−	−	*	−	−	*	−
868u025	−	*	−	*	+	*	*	*	+	−
868d050	+	*	−	−	−	*	*	−	−	−
868u050	*	+	*	+	+	+	+	+	+	+
868d075	*	−	−	−	−	−	*	−	*	−
868u075	+	*	+	*	+	+	+	+	+	+
868d100	−	*	*	−	−	−	*	−	+	−
868u100	+	+	*	+	−	+	+	+	+	−
868d125	−	−	−	*	−	−	−	−	−	−
868u125	+	+	+	+	+	+	+	+	+	+
868du0	*	−	−	−	−	−	*	−	−	−

Fig. 2. Result of the preliminary experiment.

C. Results

The result of this preliminary experiment was depicted in Fig. 2 that indicates which sounds were interpreted as "positive (+)," "negative (-)," and "undistinguishable (*)." The result showed that all 10 participants believed the PC had positive attitude for five sounds, that is, 189 ms with an upward slope range of 125 Hz (189u125), 418u125, 639u100, 639u125, and 868u125. Also, all they believed the PC had negative attitudes for five sounds, that is, 418 ms with a downward slope range of 25 Hz (418d25), 418d50, 418d75, 418d125, and 639d50. Thus, the sounds with faster increasing intonation regardless of the duration were interpreted as being positive attitudes, while the sounds that have around 500 ms with slower decreasing intonation were interpreted as being negative attitudes.

Here, among the five sounds interpreted as positive attitude, we eliminated the sound labeled 639d100 due to the slowest slope range. Also, among the five sounds interpreted as negative attitude, we did the sound 418d125 due to the fastest slope range. The rest of the remaining eight sounds were then selected for agents with different appearance in the next actual experiment.

V. Experiment

The purpose of this experiment was to investigate the effects of the agents' appearance on how participants interpreted the agents' attitudes. Specifically, the participants were presented the selected sounds in the preliminary experiment by agents that have different appearances, e.g., the Mindstorms robot, AIBO robot, and the normal laptop PC (see Fig. 3). The participants were then asked to determine the appropriate attitudes among these three attitudes, i.e., positive, negative or undistinguishable, based on the expressed sounds made by these agents.

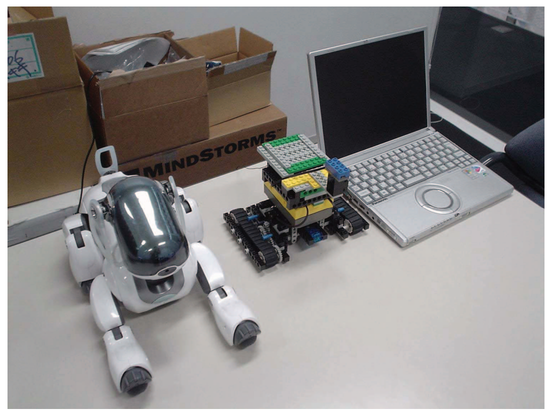

Fig. 3. AIBO robot, Mindstorms robot, and the laptop PC (from left to right).

A. Participants

20 Japanese university students (17 men and 3 women; 19-24 years old) participated. These participants were not familiar with robots or these toys, and had not participated in the former preliminary experiment. Hearing tests established that none of them had any hearing problems.

B. Procedure

Firstly, an experimenter gave the instruction, like "This is a monitoring research to evaluate three agents by means of questionnaire." The participants were then explained that the concrete task was to select the one of the three attitudes "positive," "negative," or "undistinguishable" after the agent expressed certain information. All participants experienced the following three experimental conditions.

1. Eight sounds expressed by Mindstorms (MS-condition): the eight sounds came from an FM radio tuner mounted on the Mindstorms. This radio tuner received the transmitted sounds from a sound expressing PC (Fig. 4).
2. Eight sounds expressed by AIBO (AIBO-condition):

the sounds were presented using AIBO's operating software "AIBO entertainment player" that was installed in an AIBO operating PC. This software offered to control the AIBO remotely.

3. Eight sounds expressed by the laptop PC (PC-condition): The nearly same conditions as those in the preliminary experiment were used. This laptop PC was remotely operated by a sound expressing PC.

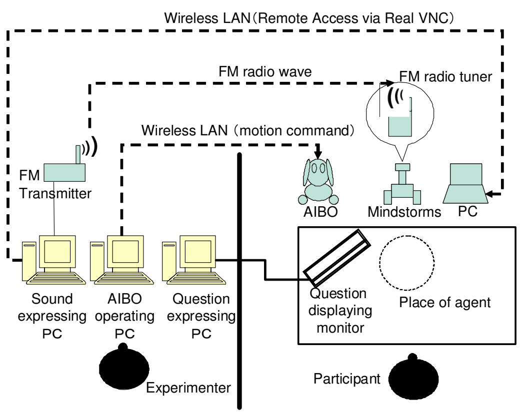

Fig. 4. Experimental Setting.

All participants experienced these three conditions in random order. In all three conditions, the eight sounds were randomly presented to the participants. Actually, the experiencing order of the experimental conditions and the presenting order of the eight sounds were counterbalanced for the participants.

C. Results

We calculated the interpretation rates, which indicated how many times the participants succeeded in correctly determining the agents' attitudes in all three experimental conditions. The results were that the participants have interpretation rates of 4.45 for eight experimental stimuli in the MS-condition, 4.40 in the AIBO-condition, and the 6.65 in the PC-condition (Fig. 5). The reason that the interpretation rate in the PC-condition was lower than ones in the preliminary experiment (the interpretation rate in the preliminary experiment was 8.0 because we utilized the sounds that all 10 participants showed the same interpretation) was that there were two participants who answered "undistinguishable" for the all experimental trial.

The results of ANOVA on the interpretation rates showed significant differences in these three experimental conditions ($F(2,38)=15.56$, $p<.01$(**)), and a multiple comparison using an LSD test showed significant differences between the PC-condition and the other two conditions (Mse=2.9421, 5% level). Thus, these results showed that the participants' interpretation rates for the same sound stimuli differed based on each agent's appearances. Simply stated, the participants showed the higher interpretation rate in the PC-condition, while they did the significantly lower rates in the MS and AIBO-conditions, even though the same sounds were presented to participants in these three conditions.

Why did the MS and AIBO conditions show the lower

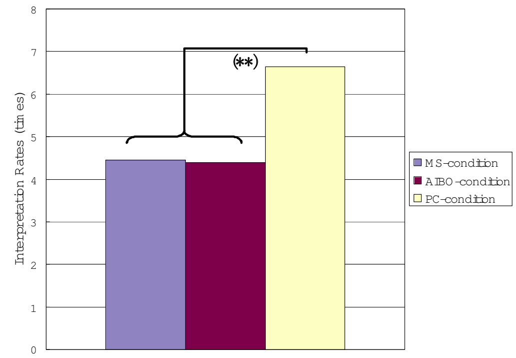

Fig. 5. Average of Interpretation rate.

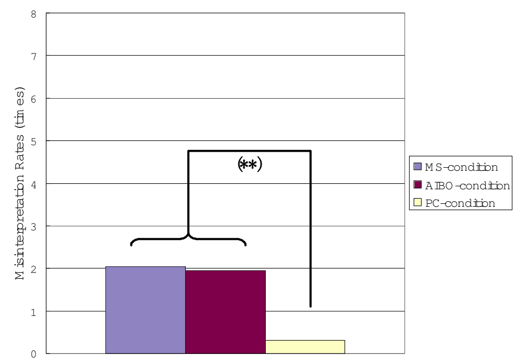

Fig. 6. Average of Misinterpretation rate.

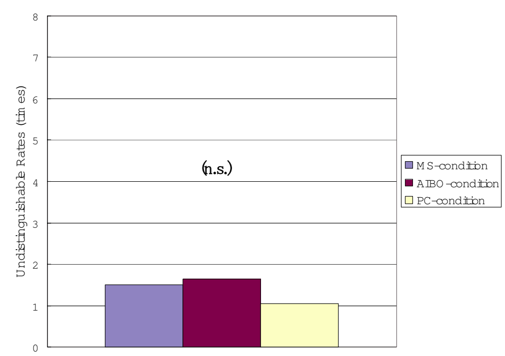

Fig. 7. Average of Undistinguishable rate.

interpretation rates? To tackle with this issue, we investigated whether the participants selected the opposite or undistinguishable attitudes, especially when the participants selected the wrong attitudes. Specifically, we calculated the misinterpretation rates, which indicated how many times the participants failed to determine the agents' attitudes correctly in all three experimental conditions, and the undistinguishable rates, which indicated how many times they selected the "undistinguishable attitude." The results were that, in the MS-condition (the interpretation rates of 4.45), the participants had the misinterpretation rates of 2.05 and the undistinguishable rates of 1.50. In AIBO-condition (the interpretation rates of 4.40), they did the misinterpretation rates of 1.95 and the undistinguishable rates of 1.65. In PC-condition (the interpretation rate of 6.65), they did the misinterpretation rate of 0.30 and the undistinguishable rate of 1.05 (Figs. 6 and 7).

The results of ANOVA on the misinterpretation rates showed the significant differences in three experimental conditions ($F(2,38)=13.42$, $p<.01$(**)), and a multiple comparison using an LSD test showed significant difference between the PC-condition and the other two conditions. Also the results of ANOVA on the undistinguishable rates showed that there was no significant differences among three experimental conditions ($F(2,38)=1.04$, n.s.). Therefore, it was clarified that the lower interpretation in MS and AIBO-condition was caused by the participants' misinterpretation on the presented sounds, not by their undistinguishable answers.

VI. Discussion

Eight artificial sounds selected in the preliminary experiment were presented to the participants by a Mindstorms, AIBO, and PC. The participants' interpretation rates, indicating how many times the participants selected the correct attitudes, were then investigated. The results were that the interpretation rates when a PC expressed these sounds were significantly higher than the rates when a Mindstorms and AIBO expressed them. This difference revealed that the agents' different appearances affected people's interpretations of the agents' attitudes, even though these agents expressed information that was completely the same.

We also focused on the case of the MS and AIBO conditions that the participants showed the lower interpretation rates, and investigated whether the participants selected the opposite or undistinguishable attitudes. The results were that the lower interpretation in MS and AIBO-condition was caused by the participants' misinterpretation on the presented sounds not by their undistinguishable answers. This revealed that the agents' different appearance caused the people's misinterpretations of the agents' attitudes, again, even though these agents expressed the same information.

First, let us consider why the PC condition showed the higher interpretation rates compared with the other conditions. One reason is that the presented eight sounds were selected in the preliminary experiment that these sounds were presented by a laptop PC, which was also used in the PC condition. Thus, these sounds may have been effective only for informing people of primitive attitudes when they were presented by a laptop PC. This phenomenon may be rooted in the fact that the PC expressing beep-like sounds was very familiar for all participants, while MS and AIBO expressing these sounds was unexpected and not familiar for them.

According to this familiarity between the agents' appearance and its expressed information, a Japanese robot designer Sonoyama [17] argued that most people have strong tendencies to expect higher abilities and functions on the various types of robots; that is, they expects the fluent speech sounds, smooth verbal conversations and so on. This argument supports our argument mentioned in the Introduction that "people are said to determine agents' behavior models based on the appearance of the agents." In our experiments, we designed that the Mindstorms and AIBO robot just expressed the artificial sounds that were quite similar with the beep sounds expressed by the normal computers. Therefore, it would be an outside of the scopes for the participants to receive such sounds from the robot so that they eventually would be disappointed by these robots. This might cause the lower interpretation rates on the MS and AIBO experimental conditions.

Therefore, to clarify the relationship between the agents' appearance and its expressed information, it strongly requires in investigating the relationship between the agents' appearance, these expected functions and their actual functions. We then proposed "an Adaptation Gap Hypothesis" to capture this relationship. This adaptation gap (AG) can be defined as follows:

$$AG = F - \overline{F}$$

Here, F is the agent's actual function and $\overline{F}$ is the agent's expected function based on its appearance. This hypothesis can handle the following three situations.

I. $AG = 0\left(F = \overline{F}\right)$: When the actual function equals to the expected function. It is said that there is no adaptation gap. In this case, the agent would be regarded as an instrument for people.

II. $AG < 0\left(F < \overline{F}\right)$: When the expected function is overestimated compared with the actual function. It is said that there is a negative adaptation gap. In this case, most people would be disappointed by the agent and stop interacting with this agent (Fig. 8, left).

III. $AG > 0\left(F > \overline{F}\right)$: When the actual function exceeds the expected function. It is said that there is a positive adaptation gap. In this case, most people would not be disappointed the agent and continue interacting with this agent (Fig. 8, right).

Fig. 8 depicted the concrete example of this hypothesis. For example, in the left of the Fig. 8, when one faces to the humanoid robot, s/he would expect human-like behaviors from this robot (higher $\overline{F}$ value). However, this robot grasped a pen on the table with spending two or three minutes or failed to detect her/his verbal commands frequently, s/he eventually noticed this robot's actual function F which is quite lower than $\overline{F}$. In this case s/he would be disappointed by this robot. On the other hand, in the right of the Fig. 8, when one faces to the typical machine-like robot, s/he would expect lower functions (lower $\overline{F}$ value). However, the robot succeeded in behaving as s/he wants smoothly and s/he then noticed the robot's F which is higher than $\overline{F}$. In this case, s/he would have good impressions on this robot and continue interacting with this.

Here, it seemed that PC condition in our experiment might fit to the case of $AG = 0\left(F = \overline{F}\right)$ and MS and AIBO conditions would do the case of $AG < 0\left(F < \overline{F}\right)$, and these situations would affect the people's interpretations of the presented sounds. This interpretation would show why the MS and AIBO conditions' interpretation rates were lower than PC-condition. We are then planning to conduct a psychological experiment whether this adaptation gap hypothesis can be observed in the relationship between various artifacts and people. The results of this consecutive experiment would contribute the clarification of the issue "how does appearance of agents affect how people interpret the agents' attitudes."

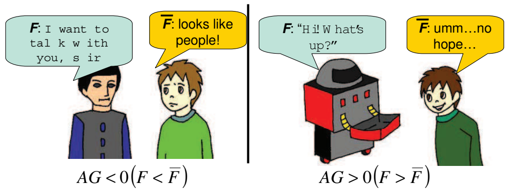

Fig. 8. Adaptation Gap Hypothesis.

And this would also contribute to generalize the Mori's uncanny valley theory [19] that as a robot is made more human-like in its appearance and motion, the emotional response from a human being to the robot will become increasingly positive and empathic, until a point is reached beyond which the response quickly becomes that of strong repulsion. However, as the appearance and motion continue to become less distinguishable from a human being, the emotional response becomes positive once more and approaches human-to-human empathy levels.

VII. CONCLUSIONS

We conducted psychological experiments where participants were presented artificial sounds that can make people estimate specific agents' primitive attitude from three kinds of agents in order to clarify the relationship between the agents' appearances and their expressed information. The participants' interpretation rates, indicating how many times the participants selected the correct attitudes, were then investigated. The results were that the interpretation rates when a PC expressed these sounds were significantly higher than the rates when a Mindstorms and AIBO expressed them. This difference revealed that the agents' different appearances affected people's interpretations of the agents' attitudes, even though these agents expressed information that was completely the same. This result also showed that the lower interpretation in MS and AIBO-condition was caused by the participants' misinterpretation on the presented sounds not by their undistinguishable answers. This revealed that the agents' different appearance caused the people's misinterpretations of the agents' attitudes, again, even though these agents expressed the same information.

It was then clarified that people's interpretation were strongly affected by the agents' appearance and by the expected functions based on their appearance. Therefore, to clarify the relationship between the agents' appearance and its expressed information, it strongly required in investigating the relationship between the agents' appearance, these expected functions and their actual functions. We then propose "an Adaptation Gap Hypothesis" to capture this relationship.

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