Recognition for Psychological Boundary of Robot

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***Abstract*—We discuss the recognition of robot's boundaries. Humans think about psychological boundaries of robots in addition to physical ones while interacting with them. We made two hypotheses regarding psychological boundaries. Firstly, these boundaries are affected by the context surrounding the robot. Secondly, these boundaries are controllable. We conducted an experiment with 60 Japanese males and females aged 18–27. Each participant was told a message that "slide me slightly" from a robot while the participant was interacting with it. We analyzed the participants' actions and questionnaires so as to confirm where of their sight was considered to be "me". From this analysis, we confirmed that our hypotheses are both true.**

***Index Terms*—Experimentation, Human Factors, Reliability, Psychology**

I. Introduction

To investigate effective interaction scenarios, psychological research for the recognition of robots is required. In this paper, we address the recognition of robot's boundaries.

Humans assume affordances from anthropomorphic shaped objects. At the same time, humans feel some agents around them. Using these phenomena, Ogawa et al. proposed the ITACO system, in which a computer agent transits among several electronic devices [1]. This system effectively increases user's familiarity with the agent. Also, they conducted experiments for the recognition of agents using anthropomorphic robot parts [2]. In these research projects, interesting tools were proposed based on the characteristics of the recognition for the boundaries of robots. However, the mechanism of the recognition has not been addressed.

On the other hand, many papers are reported around the recognition for the boundaries of self bodies of humans in the field of psychology and brain science. For example, the rubber hand illusion is a useful method to investigate it [3], [4], [5]. However, all of these works are only related to self bodies of humans.

To investigate the recognition for psychological boundaries of robots, we made two hypotheses. (1) Recognition of the boundaries can be affected by context. (2) Recognition of the boundaries is controllable.

II. Apparatus and Environment

For the apparatus, we prepared a robot, a laptop PC, a wagon, a cloth case, a video camera, a blackout curtain, a desk, and a chair. Figure 1 shows the appearance of the robot. This robot was designed to express an anthropomorphic appearance with a plain design. This robot is equipped with an LED switch at its head, LCD display on its front surface, a Felica reader at its bottom, and a speaker inside it. The LED switch expresses color and receive on/off input. The LCD display expresses messages using characters. All of these devices are controllable from the laptop PC using a ZigBee wireless connection.

Fig. 1. Robot.

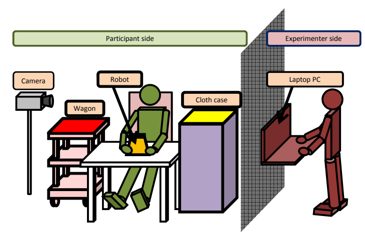

Fig. 2. Experimental environment.

Figure 2 shows the schematic of the experimental environment. To shut out noisy visual stimulus, we set a blackout curtain around the experimental space. We separated the experimenter and the participant using the curtain, and recorded the space using the camera so as to use the Wizard of Oz method [6]. The participant that sat in the chair was instructed to interact with the robot. The participant was allowed to place the robot on the desk, the wagon, or the cloth case. The wagon and cloth case were equipped with a cover and an LED according to experimental conditions (Fig. 3).

III. Experiment

The participants were 60 Japanese males and females aged 18–27. They passed stress tests and agreed on the experimental process. The experimental process was accepted by the ethic committee of Waseda University.

We set four experimental conditions (Table I). Each participant was examined only using one of them. Each participant firstly received instructions, then interacted with the robot, and replied to a questionnaire after the interaction.

An experimenter explained how to handle the robot, safety notation, and so on. Also, the experimenter told the participants that "Please interact with the robot within 20 minutes."

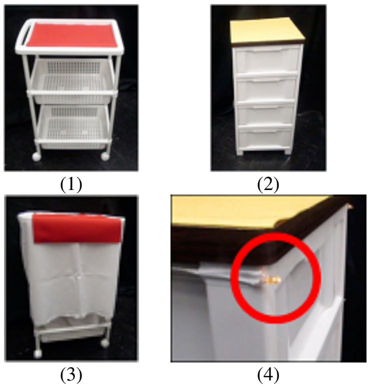

Fig. 3. Wagon and cloth case.

(1)(2) Wagon and cloth case, respectively. (3) Covered wagon. (4) The cloth case, which was equipped with an LED.

TABLE I
EXPERIMENTAL CONDITIONS

Condition 1	Plain wagon and cloth case were used (Fig. 3 (1),(2)) (control condition)
Condition 2	Wagon was covered (Fig. 3 (3))
Condition 3	Addition to Condition 2, Cloth case was equipped with an LED. When the robot was on the cloth case, LED was flicked (Fig. 3 (3),(4))
Condition 4	Addition to Condition 3, an experimenter instructed that the wagon and cloth case are both robots.

Moreover, in experimental Condition 4, explanations were given at this timing.

In the interactions, the robot's actions were remotely controlled by the experimenter. When the participant placed the robot on the wagon or cloth case, the experimenter moved the robot with unique motions according to the placed objects. After 10 minutes interaction, the experimenter showed a message that "slide me slightly" on the LCD display when the participant placed the robot on one of the objects. The actions of the participants were recorded.

We arranged a list of questions. (1) Did you detect some change when the robot was placed on the wagon or cloth case. (yes/no) (2) (If Question1 is "yes".) What do you think was the meaning of the change. (3) Maybe, you got an instruction, "slide me slightly" from the robot. Where do you think the region of "me" is? Especially in Question3, participants drew the region on the figure in Fig.4.

IV. RESULTS

A. Results of the Drawing

Figure 5 shows the region of "me", which the participants drew. Figures (1)–(3) show typical results. 46, 3, and 4 participants drew in the same way, respectively. We excluded the data of the other 7 participants from our analysis, because they drew the figures different than (1)–(3), and they are difficult to interpret.

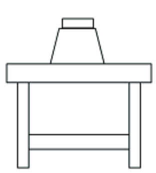

Fig. 4. Presented figure.

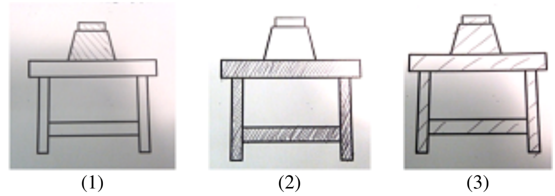

Fig. 5. Classification of drawing results.

(1) 46 participants drew the robot. (2) 3 participants drew the table (wagon or cloth case). (3) 4 participants drew the robot and table. 7 participants drew in different manner than (1)–(3).

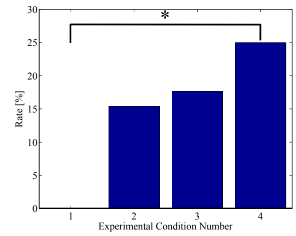

Fig. 6. Rate of participant who drew the table. "*" means $p \leq 0.05$.

Figure 6 shows the rate of participants (except the excluded participants), who drew the table (Fig. 5 (2) and (3)). In Condition 1, all of the participants drew as in Figure 5 (1). On the other hand, in Condition 4, 25% participants drew the table.

The result of Fig. 6 shows that the recognition for the psychological boundary is affected by the environmental context, uncertainty. The conditions, covering wagon, attaching LED to cloth case, and the instruction for "The tables are also robots", increase psychological uncertainty for the objects where a robot was placed. Also, the recognition was controllable.

V. CONCLUSION

In this paper, we conducted a psychological experiment using a robot so as to confirm the factors that affect the recognition of robot's boundary. From the results, we could confirm that uncertainty of the surrounding environment affects the recognition. Also, the recognition was controlled by the level of uncertainty.

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