Effect on User Impression of Robot's Task Dependent Uniform

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Abstract: In this paper, we investigated the impressions of users when a humanoid robot is dressed in uniforms that match tasks. Increasingly more robots, such as humanoid robots, can perform multiple tasks on a single machine. In such a case, it is important to design the appearance of robots and their uniforms according to the content of the task because these factors are known to express their level of expertise and technical ability. In our proposed method, a robot changes its appearance dynamically by replacing its uniform with one that matches a task before performing it. The results of our simulator-based experiments indicated that, compared with robots that do not wear a uniform, robots that changed their uniform to match a task were interpreted as being more appropriate, even after making mistakes.

1 INTRODUCTION

In recent years, the range of applications for robots is rapidly expanding because of advances in not only the industrial field, but also fields such as medical care (Heerink et al., 2016), nursing (Huisman and Kort, 2019), agriculture (Hejazipoor et al., 2021), forestry (Parker et al., 2016) and fisheries (Takagi et al., 2016), and education (Belpaeme et al., 2018). When robots become more widespread than they are today, their appearance will be one of the most important factors because it is an element that can provide clear information about a robot and its intended function.

Many researchers have been studying the appearance of robots. Złotowski et al. (Złotowski et al., 2020) reported that the appearance of a robot is important for people in regard to their perceptions of its capabilities and preferences for it to perform a specific task. Komatsu et al. (Komatsu and Yamada, 2008) reported that the same information is interpreted differently by users depending on the appearance of a robot. In a prisoner's dilemma game on a computer, Kiesler et al. (Kiesler et al., 1996) found that users who had owned a dog were more likely to cooperate with a dog-shaped robot than were those who had not. Komatsu et al. (Komatsu and Yamada, 2011) reported that an adaptation gap, that is, a difference between the functions users expect based on a robot's appearance and the functions users perceive through actual interactions, significantly affects robot evaluations. Song et al. (Song and Yamada, 2019) investigated users interpretation for LED expression by a cleaning robot. Although these findings indicate that the appearance of a robot leads to significant biases among users, few studies have investigated robot clothing or software agents.

Here, we focus on clothing in terms of a robot's appearance and investigate the effects of changing clothing to match a task on the impressions of users and their evaluations of its work performance. The public has shown interest in robotic clothing, and an event on robot fashion has already been held [1]. From a functional perspective, clothing provides insulation against cold and protection against ultraviolet rays, wind, rain, and other environmental hazards (Havenith, 2002). Also, as social effects, uniforms can convey expertise, position, qualifications, and membership in a group (Joseph and Alex, 1972). Singer et al. (Singer and Singer, 1985) investigated the effects of police uniforms and found that police officers who were photographed in their uniforms were perceived as more competent, reliable, intelligent, and helpful compared with a face-only photograph or a full-length photograph dressed in civilian clothing. Shao et al. (Shao et al., 2004) investigated the relationship between consumers' motivation to buy and employees' clothing and found that more appropriate employee clothing improved customers' motivation to buy.

[1] https://www.nippon.com/en/views/b00911/

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Although there are not many examples of research that allow robots to wear clothes, Ledge et al. (Legde and Cunningham, 2019) have reported that the virtual agents’ personality characteristics that users interpret are influenced by the agents’ clothing. However, their investigation did not cover dynamically changing clothing. By adapting the effects of a uniform to robots, functionally, the robot will be prevented from being soiled by substances such as oil, and socially, the robot will express its specialty as well as a human would. In addition, since autonomous robots can carry out tasks without clear instructions, the expression of clothing may become a natural way to transmit such information to the user, in addition to the actual function. For these reasons, uniforms may be beneficial as an appearance effect for robots. Therefore, this simulation-based study aimed to investigate the possible impression effects on users of a robot changing its uniform to match a task.

2 SIMULATOR-BASED UNIFORM CHANGING ROBOT

We developed a uniform changing robot and an original housekeeping simulator on a Web-based platform.

2.1 Uniform Changing Robot

Figure 1 shows the robots we designed in the housekeeping simulator, one wearing no uniform and the other wearing a task-specific uniform. The robot’s appearance is inspired by Pepper, the widely known semi-humanoid robot manufactured by SoftBank, because Pepper has a commonly known design that was developed considering the uncanny valley (Pandey and Gelin, 2018). The uncanny valley is a concept in which an artifact resembles an existing organism so closely that it causes people to have an emotional response (Mathur and Reichling, 2016; Ho and MacDorman, 2010). This effect is one of the important design guidelines for the robot’s appearance.

The uniforms were designed based on the robot’s three housekeeping tasks: cleaning, washing, and cooking. In the cleaning task, the robot wears a blue cloth and a hat like a building cleaner. In the washing task, the robot wears an apron and a bandana. In the cooking task, the robot wears a chef’s cap and coat.

2.2 Housekeeping Task Simulator

Bugmann et al. reported that housework was the most important job for domestic robots, as many people want robots to perform the cleaning, washing, and

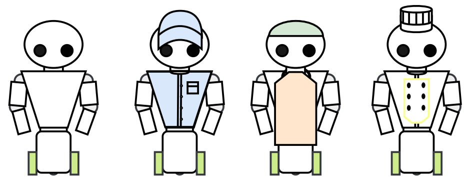

Figure 1: Appearance of robot in each task.

cooking (Bugmann and Copleston, 2011). Moreover, Kang et al. conducted a study based on the three scenarios of cleaning, washing, and cooking in research to investigate the necessary functions for domestic robots (Kang et al., 2020). Based on those previous studies, the present study designed household cleaning, washing, and cooking tasks for the robot to perform. Figure 2 shows the developed housekeeping simulator consisting of a room in an ordinary home. The robot in the simulator can move up, down, left, and right within the room to perform the three tasks of cleaning, washing, and cooking. Objects in the simulator such as the refrigerator and kitchen are animated when the robot manipulates them. Figure 3 shows the ways the kitchen is animated before, during, and after cooking.

2.3 User Interface

The right side of Figure 2shows a remote control and messages for users. Users request the robot to perform a task indicated by a button on the remote control. The tasks to be performed are automatically displayed on the screen in the message area, and the users can then manipulate the remote control.

2.4 Robot Behavior

Figure 4 shows the robot behavior for each task. The robot changes its uniform whenever it begins to perform a task at the initial position near the door in the room. The tasks to be performed by the robot were set as cleaning, washing, and cooking. In the cleaning task, the robot and moves slowly across the floor and vacuums. As the robot cleans, the scattered debris on the floor gradually fades in color until an animation plays in which the floor is shiny. In the washing task, the robot moves to a clothesline and collects washed clothes before moving to place them on a table. In the cooking task, the robot moves in front of the refrigerator and removes food before using the frying pan and bringing the prepared food to a table.

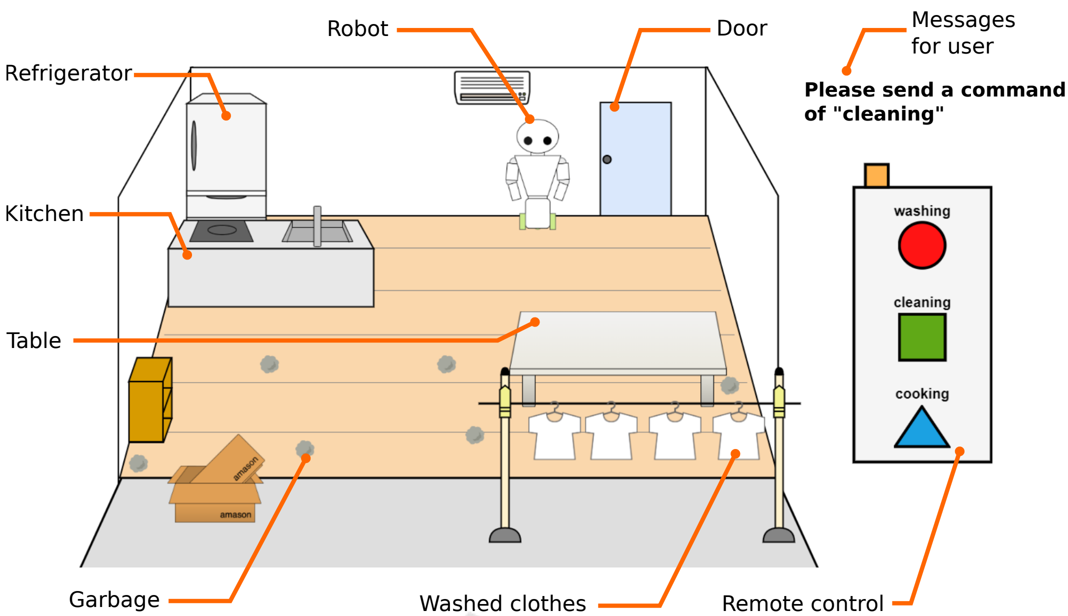

Figure 2: Housekeeping task simulator.

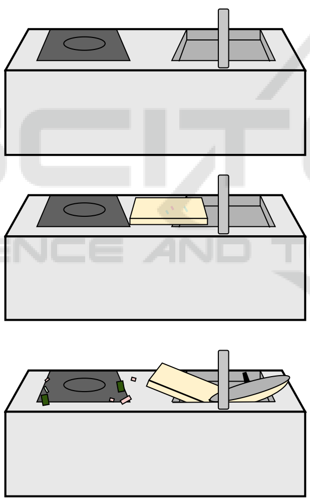

Figure 3: Animations in kitchen.

3 EXPERIMENT

To investigate user impressions of the robot changing its uniform according to the requested task, we performed experiments with 20 male university students (mean age = 22.1, standard deviation = 0.72). The participants were requested to send commands to the robot in the simulator according to the instructions displayed on the screen.

3.1 Task Incompleteness

In the experiment, the robot was set to not accomplish each task completely to increase the degree of freedom of the subjective evaluations of its behavior and clarify the effects of uniform changing. In the cleaning task, a few pieces of debris were left on the floor. In the washing task, a few hangers were dropped and left on the floor. In the cooking task, the pans and cutting boards used for cooking were left in the sink, and some small pieces of food were left around the range.

3.2 Task Evaluation by the Participants

At the end of each task, to confirm the users' individual interpretations of and satisfaction with the performed task, the participants were asked to input their judgment of the quality of each task performed by the robot along with their subjective satisfaction. Figure 5 shows the evaluation window and score sliders for each task. The score ranged from 0 (unsatisfied or low quality) to 9 (satisfied or high quality). As soon as a task was finished, the evaluation window was displayed at the top of the simulator screen. When a participant finished inputting scores, messages with further instructions were displayed at the top of the remote control.

3.3 Experimental Procedure

The participants were instructed about the experiment as follows.

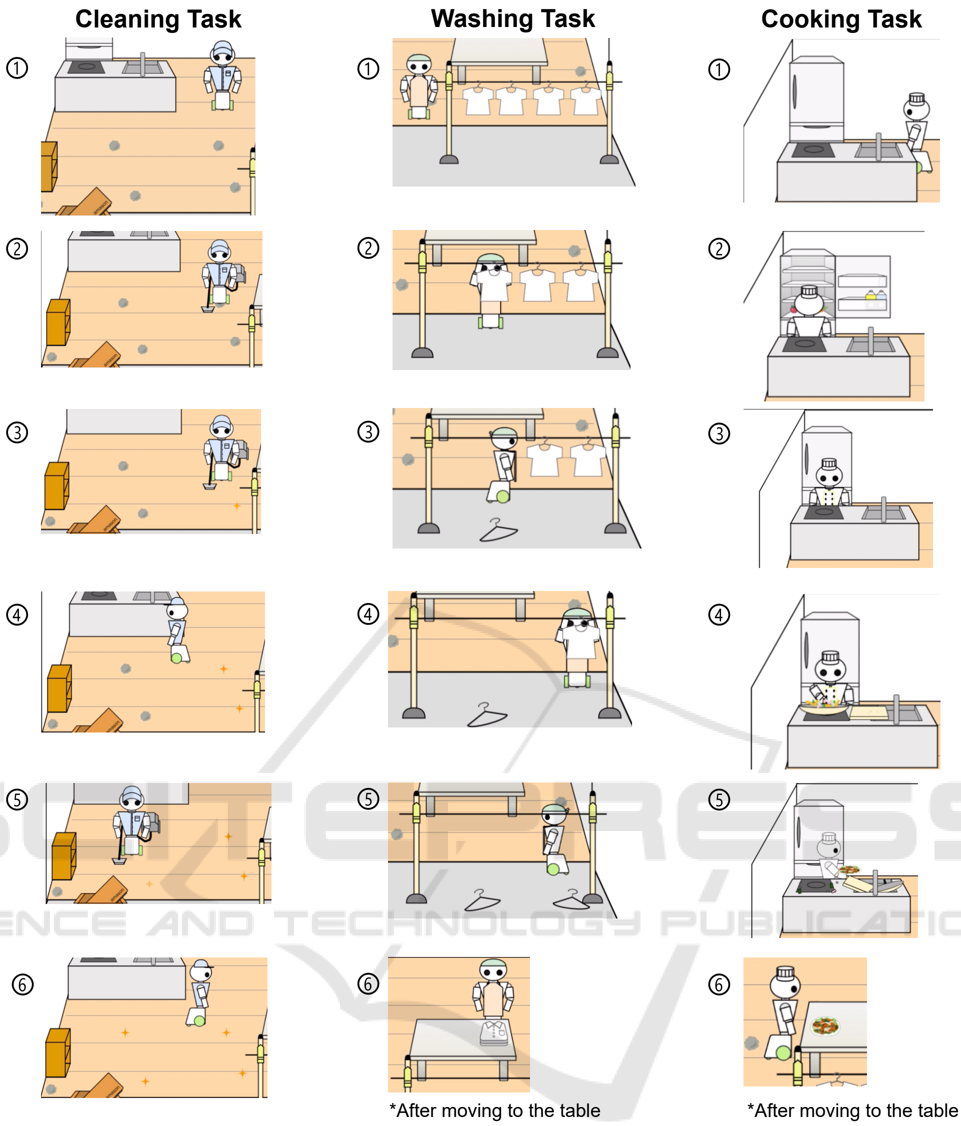

Figure 4: Robot behavior in each task.

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- It will take about 15 minutes to complete this experiment.
- Manipulate the remote control on the screen to request that the robot perform a task.
- Observe the behavior of the robot and check that the task was performed appropriately.
- Whenever the task is completed, input your subjective satisfaction and quality scores.

We did not provide any information about the robot's uniform or task incompleteness. During the experiment, the participants sat in a chair in front of a 24-inch monitor on a desk.

3.4 Experimental Conditions

The experiments were performed under two conditions: a uniform changing condition and a no-uniform condition. We used a between-participants experimental design. In the uniform changing condition, the robot changes its uniform to match the task before starting it. After finishing the task, the robot moves back to the initial position near the door in the simulation room and removes the uniform. In the no-uniform condition, the robot performs a task while wearing no uniform. The order of the robot's tasks was randomized under each condition.

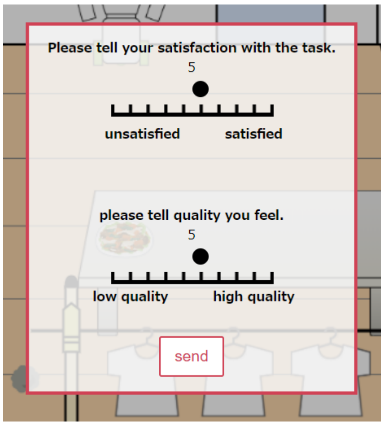

Figure 5: Evaluation window and score sliders for each task.

3.5 Evaluation Indices

The participants were asked to reply to a questionnaire survey after the robot had finished all its tasks. The questionnaire was composed of seven Likert-type scaled questions and a free writing area. The questionnaire items were based on part of Heerink's model (Heerink et al., 2010), which includes Davis's Technology Acceptance Model (TAM) (Davis, 1989) and items related to perceived enjoyment and trust. The items related to trust, perceived usefulness, intention to use, and social presence were used in the present questionnaire. In addition, the items described in section 3.2 related to the clothing change, subjective quality of the task, and subjective satisfaction of the task were used. The independent variable was uniform changing or not, and the dependent variables were the satisfaction score, the quality score, and the questionnaire items.

4 RESULTS

The Mann–Whitney U test was used to conduct the statistical analysis for the task evaluation (satisfaction and quality) and questionnaire items after the experiment (Mann and Whitney, 1947). This is because the number of experimenters was small (N = 10 for each condition), so it was difficult to judge whether to follow a normal distribution (Nachar, 2008).

Table 1 shows the satisfaction scores for the robot tasks and the results of the statistical analysis. Although no significant difference was seen in the satisfaction scores between conditions, all mean values for the uniform changing condition were higher than those for the no-uniform condition.

Table 2 shows the quality scores for the robot tasks and the result of the statistical analysis. We conducted the Mann–Whitney U test for both scores and found no significant difference between conditions. However, all mean values for the uniform changing condition were the same or higher than those for the no-uniform condition.

Table 3 shows the questionnaire scores and the results of the statistical analysis using the Mann–Whitney U test. A significant difference was found between conditions for Q4 ($U = 18.0, df = 18.0, p = 0.015$).

Table 4 shows the frequency and order of occurrence of each task throughout the experiment. Although the order of the tasks were randomized, no extreme bias was observed.

5 DISCUSSIONS

5.1 Effects of Changing Uniforms by Robots

No significant differences in satisfaction and quality scores were found between conditions. However, all mean values for the uniform changing condition were the same or higher than those for the no-uniform condition. These results suggest that users of the robot under the uniform changing condition perceived the same or better satisfaction and quality compared with the robot under the no-uniform condition, and that no users experienced any negative effects of the uniform change.

A significant difference was found between conditions for Q4. This result shows that the participants interpreted the behavior of the robot under the uniform changing condition as being more appropriate, even if the task was incomplete, compared with that under the no-uniform condition. One participant's free comment ("I felt like the robot was choosing the right clothes for the job") also supports the effect of the uniform changing condition. Although no significant differences were seen in the other items between conditions, Q5 and Q9 had higher values under the uniform changing condition. These results suggests that the participants noticed the incompleteness of the tasks more clearly under the uniform changing condition than under the no-uniform condition; however, the participants preferred the robot in the uniform changing condition over the robot in the no-uniform condition. Regarding whether the uniform was appropriate, the results of Q1 indicated that more participants recognized the change of clothing. How-

Table 1: Satisfaction scores for robot tasks.

	Uniform changing condition		No-uniform condition				
Satisfaction	Mean	SD	Mean	SD	U value	df	p value
Cleaning	4.90	1.85	4.20	2.20	42.5	18.0	0.591
Washing	6.80	1.55	5.40	2.76	35.0	18.0	0.266
Cooking	5.90	2.38	5.70	2.83	32.5	18.0	0.193

Table 2: Quality scores for robot tasks.

	Uniform changing condition		No-uniform condition				
Achievement	Mean	SD	Mean	SD	U value	df	p value
Cleaning	4.80	1.81	3.50	1.96	42.0	18.0	0.558
Washing	7.30	1.57	6.90	1.66	49.0	18.0	0.969
Cooking	7.40	1.84	7.40	1.51	47.5	18.0	0.869

Table 3: Questionnaire scores.

		Uniform changing condition		No-uniform condition				
No.	Question	Mean	SD	Mean	SD	U value	df	p value
Q1	How many kinds of clothes did you think there were?	2.89	1.01	1.44	0.78	–	–	–
Q2	Do you think the robot completed the task quickly?	5.60	0.70	5.20	1.87	50.0	18.0	1.000
Q3	Do you think the robot is reliable?	4.30	1.16	4.40	1.78	44.0	18.0	0.670
Q4	Do you think the robot's actions in the task were appropriate?	6.20	1.03	4.30	1.77	18.0	18.0	0.015
Q5	Do you think the robot made many mistakes during the task?	5.30	1.34	4.40	2.01	38.0	18.0	0.369
Q6	Do you think the robot has feelings?	2.70	2.16	2.10	1.66	41.5	18.0	0.522
Q7	Was it easy to check the movement of the robot on the screen?	6.50	0.53	6.60	0.70	42.5	18.0	0.539
Q8	Did you want to ask the robot to perform other tasks?	4.60	1.90	4.70	2.16	47.0	18.0	0.847
Q9	Would you want to use the robot daily?	4.20	1.75	3.40	1.78	36.5	18.0	0.313
Q10	Did you command the robot correctly?	5.80	1.87	6.10	1.29	47.0	18.0	0.835

Table 4: Frequency and order of occurrence of each task.

Task	1st	2nd	3rd
Cleaning	8	6	6
Washing	6	7	7
Cooking	6	7	7

ever, no comments indicating that the participants felt uncomfortable about the robot's uniform were seen in the questionnaires or interviews after the experiment. On the other hand, one participant noted that "I thought it was strange to wear a hat while cooking when the robot didn't have hair." We designed the robot in order to protect it from effects such as fouling, but we found that there was still a certain sense of incongruity regarding its clothing. Therefore, it is considered necessary to redesign the robot clothing to avoid this incongruity.

5.2 Limitations

This study did have some limitations. First, the participants were all young males (average age: 23.1 years) and the small number of participants. Since this study targets robotic housework, it is necessary to increase the number of participants of a wider age range and female participants to verify the effectiveness of the proposed method.

Second, the experiment used a virtual robot shown in a Web browser, not a real robot. Therefore, the feasibility of the task, the presence or absence of me-

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chanical noise from the robot, and the speed of movement are factors that differ from the case of using an actual robot.

Finally, in the experiment, we used an animation-based virtual space instead of a real space. Therefore, participants may react differently when using an actual robot in a real space. In addition, the tasks performed by the robot were limited to housekeeping tasks. In housekeeping tasks, a user and a robot share a relatively small space, and there are many situations in which their activity ranges overlap. It is necessary to investigate the applicability of the proposed method not only to housekeeping tasks but also to tasks in public spaces such as commercial facilities.

6 CONCLUSION

This paper proposed a uniform changing robot and conducted experiments involving a housekeeping task simulator. In the experiments, a robot performed cleaning, washing, and cooking tasks according to the participants' commands. We investigated user impressions of robots that either wore no uniform or changed its uniform to match the task. The experimental results suggested that the participants interpreted the behavior of the robot under the uniform changing condition as being more appropriate, even if the task was incomplete, compared with that under the no uniform condition. Although the appearance of a robot can lead to significant biases among users, there have been few studies on the effects of clothing. In the present study, we investigated how the uniforms worn by robots can affect such biases. This effect can inform users that a robot has a specialty and can perform multiple tasks well, and may be effective for expressing the internal state of an autonomous robot. At present, having a robot actually change its clothes by itself remains a technical problem; however, a flexible display on the body of the robot could provide the same function as uniform changing. We plan to expand the scope of this research with participants and conduct experiments from different perspectives, because a uniform that conveys expertise, position, qualifications, and group membership could be effective for the design of robots.

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