International Journal of Control and Automation
Vol. 11, No. 5 (2018), pp.193-200
http//dx.doi.org/10.14257/ijca.2018.11.5.17

Color Maketh Robot: Classification of Expected Roles for Robots According to Colors

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Abstract

Traditionally, household appliances have been classified as white appliances and brown appliances. White appliances and brown appliances have different roles and characteristics that users expect. White household appliances help the house labor as household appliances. When purchasing white goods, consumers consider durability and efficiency as the most important consideration. On the other hand, brown household appliances are entertainment appliances, and consumers consider pleasure and reputation when purchasing brown goods. We applied this classification method to the social robots to investigate the expected roles of the social robots according to the color, to develop the social robots that meet the users' expectation, and to increase user acceptance of the robots. We conducted a two (robot color: white vs. black) within-participant experiment. Participants were asked to categorize robots into categories of white or brown goods, and to measure an overall evaluation of the robots. We found that participants tended to classify white robots as being similar to white appliances than brown appliances, and to classify black robots as being similar to brown appliances than white appliances. In addition, participants evaluated white robots more positively than black robots.

Keywords: *Categorization, Human-robot interaction, Robot Color, Robot design, User acceptance*

1. Introduction

Due to developments in robot technology, the robot market has been continually expanding [1]. Robots can be divided into industrial robots, professional service robots, and personal service robots [2]. Initially, industrial robots and professional service robots were mainly traded. On the other hand, in recent years, personal service robots owned and used by general consumers have been actively developed and marketed [3]. In the case of industrial robots and professional service robots, which have occupied the largest segment of the robot market, each robot has specific expertise and clear roles. For example, the industrial robot, C8 series, developed by Epson Robots, assembles parts using articulated robot arms [4]. da Vinci, Developed by Intuitive Surgical, is a professional service robot that facilitates complex and sophisticated surgeries [5]. Personal service robots such as Pepper [6] and JIBO [7] can provide a variety of living information and entertainment services, but their specific roles are unclear unlike the industrial robots and the professional service robots. The personal service robots mentioned above are called social robots because they interact socially with users.

Received (November 14, 2017), Review Result (March 20, 2018), Accepted (April 3, 2018)

ISSN: 2005-4297 IJCA

When a social robot enters a home, it functions as other household electric appliances. Traditional household appliances have been divided into white goods and brown goods depending on their role and color. White goods are home appliances for household labor, such as a washing machine, a refrigerator, and an air conditioner [8]. Brown goods are home appliance for leisure, such as a television, video system, and an audio system [8]. Based on the above concept of color classification, we investigated how the users classify personal robots, and what they expect from robots based on the color classification.

In Section 2, we introduce related works on traditional household appliances' categorization methods depending on the colors, and the user acceptance according to the appearance of the robot. In Section 3, we describe the study design to investigate the effects of robot color on robot classification and user acceptance. In Section 4, we show the results of the study. In Section 5, we conclude the research findings.

2. Related Studies

2.1. Social Robot

Duffy and his colleagues defined social robots as: "A physical entity embodied in a complex, dynamic, and social environment that empowered to behave in a manner conducive to its own goals and those of its community" [9]. People tend to interact with animal, plants and objects in a way that interact with other people [10]. Unlike other objects, people perceive the robot not only as an object, but also as a socially interactive entity [11]. In addition, because social robots can move, and express its thoughts and emotions, the social cues used between people can apply to human-robot interaction [12]. In other words, social robots do their part when they achieve their goals with cognizing and expressing the social cues commonly used in the social environment.

Robot developers and designers have made various attempts to design a robot that seems to be a social entity which is capable of social interaction. Breazeal and her colleagues studied how social robots that collaborated with humans would react non-verbally to human behavior in order to develop the social robot which could interact with humans more socially [13]. Walters *et al.*'s study found that people evaluated the robots' personality differently depending on the distance the robots approached themselves [14]. Fussell and his colleagues' study, on the other hand, showed that people felt more lifelikeness when the robot spoke politely than when the robot spoke impolitely [15].

Various social robots have been developed as a result of actively researching verbal and non-verbal social cues of robots in order to design the robots more social. Pepper is a robot developed by Softbank [6]. Pepper can communicate emotionally with users. Pepper can play with quizzes, simple games, and playing music with gazing at users and expressing emotions to users [6]. PR2 is a robot developed by Willow Garage. PR2 can organize tables, and folding the laundry with gazing at users, maintaining proper distance from users [16]. In this way, Today's robots can cognize and express various social cues and perform various roles.

2.2. White Goods and Brown Goods

Household appliances can be divided into white goods and brown goods. Classification of home appliances based on color was developed by the General Electric Company (GE) [17]. Initially, GE's refrigerators, washing machines, air conditioners, and microwave ovens were designed to be in bright colors such as off-white and white, while TVs, audio equipment, and video equipment were designed to be in dark colors such as brown and black. Subsequently, white goods represented appliances for household tasks, and brown appliances represented appliances for entertainment [8], [17].

Depending on the colors of household appliances, their role, their location, and the frequency with which they were exposed to outsiders (non-family members) have been determined. These factors influenced consumption patterns. Cockburn *et al.*, found that users consider affordability and serviceability as important factors when purchasing white goods [18]. Such goods were attractive to users when their prices were low, they did not break down easily, and their maintenance cost was low [18]. In addition, white goods are expected to be simple to operate because they are used for housework, and complicated operation could add to user stress [18]. On the other hand, when purchasing brown goods, users consider pleasure and reputation than serviceability as important factors determining the purchase [18]. Brown goods usually do not perform dirty jobs, and tend to be present in a lounge or a living room [18]. Brown goods are used by all family members, provide immediate satisfaction, and are more prominently visible to guests that white goods [8]. Therefore, brown goods' trends change more quickly, and they have shorter replacement cycles than white goods [8].

2.3. Product Appearance and Consumer Acceptance

The physical appearance of the product affects new product classification as perceived by the users [19], and the expected function of the product and its perceived role is based on its physical appearance [20]. The match between the expected function and the actual performance of the product effects on the consumers' satisfaction of the product [21].

The user acceptance according to the appearance of the robot has been studied. According to Goetz et al.'s study, users preferred different types of robots depending on the type of jobs [22]. People preferred a humanlike robot than a machinelike robot for jobs requiring social skills [22]. Humanlike robots were perceived to have higher intelligence than machinelike robots [23]. Tall humanlike robots were considered more conscientious and humanlike than short humanlike robots [23]. Overall, humanlike robots were evaluated more positively than machinelike robots, but if they had a similar shape to humans above a certain level, the user's acceptance of robots dropped sharply [23, 24]. We could say that the appearance of the robot affects the user acceptance through the above studies, but there is insufficient research on how the appearance affects the expected function of the social robots.

The classification of social robot has not yet been clarified. In the case of household appliances, its role is classified based on the color. The product classification according to this color expects the function and role of the product. In order to meet the expectations of consumers, it is necessary to grasp the role that they expect according to the appearance of the robot. In the previous studies, there have been a lot of researches on the shape of robots but there is little research on the color of robots. Therefore, in this study, we investigated the color classification which is appropriate for robots not clearly classified as home appliances, and investigated robot design that meets user expectations.

3. Study Design

In this study, we conducted a two-color (robot color: white vs. black) within-participant experiment to investigate the effect of robot color on robot positioning and user acceptance.

We formulated the following hypotheses.

Hypothesis 1. Roles of robots will be classified differently based on their color.

Hypothesis 2. Appropriateness of the robots' colors will be evaluated differently based on their color.

Hypothesis 3. Overall product evaluation will be different based on robot color.

3.1. Participants

In order to reduce errors caused due to differences in intellectual level, twenty-four university graduates (10 males and 14 females) in their 20s and 30s were recruited as participants in this study.

3.2. Stimuli

A white Pepper [6] image and a black Pepper image were presented to the participants as stimuli. For darker color pepper images, the existing white pepper image were corrected to dark. A white Pepper image and a black Pepper image were presented to the participants as stimuli. For darker color pepper images, the existing white pepper image were corrected to dark. Except for color, the robots' appearance – shape, pose, and size-was the same (See Table 1).

Table 1. Stimuli

White Robot (bright color)	**Black Robot** (dark color)
	

3.3. Procedure

The participants were welcomed to the laboratory and were briefed on the experiment. After then, they saw two images of differently colored robots in random order, and the robots were evaluated after viewing each image. The participants were awarded a $ 10 gift voucher for the experiment.

3.4. Measurements

In order to explore the robots' expected roles according to the colors, we selected eight white appliances and eight brown appliances from a U.S. consumer report [25], and constructed an evaluation scale to assess user perception of robot positioning and expected role. We asked the participants to select multiple roles suitable for the robots. To find out how the robots' colors fit into the robot, appropriateness [26] was evaluated. In addition, in order to evaluate user satisfaction associated with robots of different colors, the participants were requested to perform an overall evaluation of the robots [27] (See Table 2). Both appropriateness and overall product evaluation were measured on likert 7 point scale.

Table 2. Measurement

Dependent variable (Scale)		Items
Product classification	White goods	"Cooling the air / Cleaning the air / Cleaning the house / Doing the laundry / Making coffee / Washing the dishes / Heating up food / Repairing the clothes"
	Brown goods	"Playing video / Recording video / Connecting phone call / Taking photos / Reading books / Playing TV / Playing music / Playing games"
Appropriateness (Cronbach's α=.958)		"Inappropriate color / Appropriate color" "Wrong color for task / Right color for task" "Ill-suited color / Well-suited color" "Improper color / Proper color" "Mismatched color / Matched color to task"
Product evaluation (Cronbach's α=.942)		"Very bad / Very good" "Very poor / Very excellent" "Very negative / Very positive" "Very unfavorable / Very favorable"

4. Results

We conducted statistical analyses using frequency analysis and paired t-test. Frequency analysis was used for identification of user perceptions of robot categories, and paired t-test was used for user evaluation of robot color.

4.1. Product Classification

Hypothesis 1 was supported by the data. Although the two robots differed only in color, product classification by users based on color was different. The white robot was classified as being similar to white goods 24 times (66.7 %) and as being similar to brown goods 12 times (33.3 %). The black robot was classified 15 times (41.7 %) as being similar to white goods and 21 times (58.3 %) as being similar to brown goods. The results show that people expected white robots to be able to perform work done by white appliances more than that done by brown appliances. Black robots were expected to be able to perform work done by brown appliances more than that done by white appliances (See Figure 1).

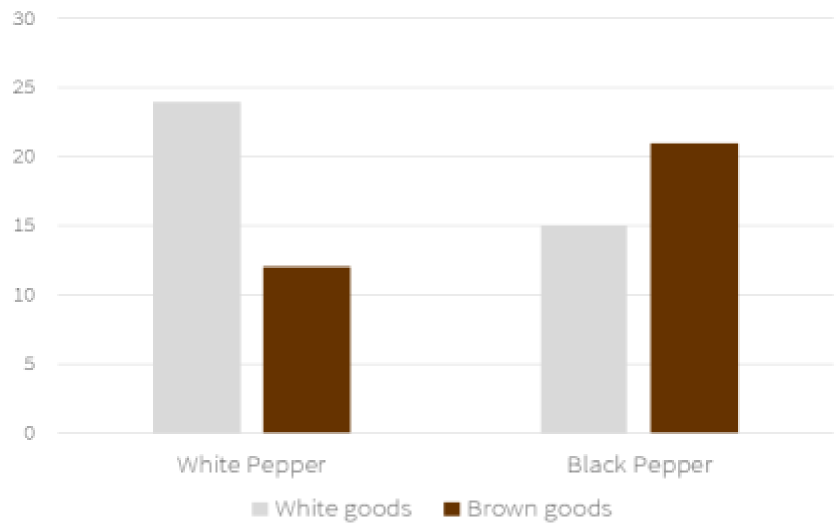

Figure 1. Product Classification

4.2. Appropriateness

Hypothesis 2 was supported by the data. The participants evaluated appropriateness of the robots' colors differently (t = 5.474, p < .001, two-tailed). Participants evaluated the white color (M = 5.18, SD = 0.78) is more appropriate for the robot than black robot (M = 3.27, SD = 1.09) (See Figure 2.).

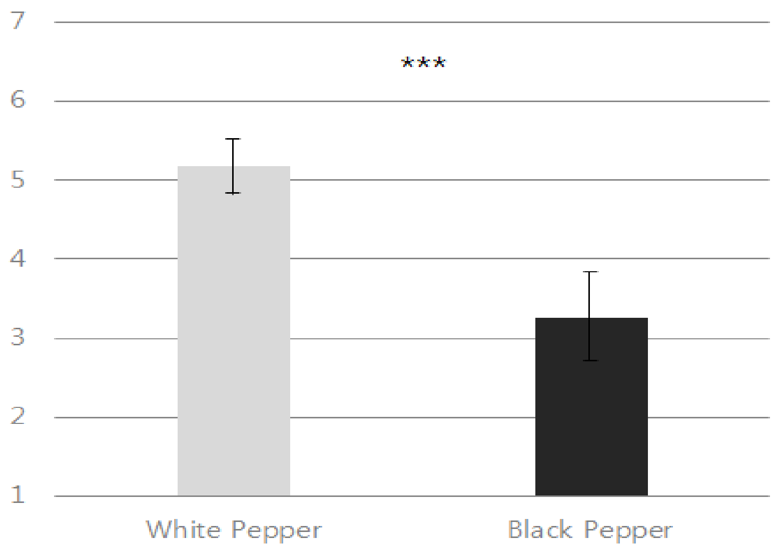

Figure 2. Appropriateness

4.3. Product Evaluation

Hypothesis 3 was also supported by the data. The participants evaluated the robots differently based on robot color (t = 2.377, p < .05, two-tailed). Participants evaluated the white robot (M = 5.11, SD = 0.78) more positively than they did the black robot (M = 4.22, SD = 0.83). The results indicate that user acceptance of humanoid robots is higher when the robot is white in color (See Figure 3).

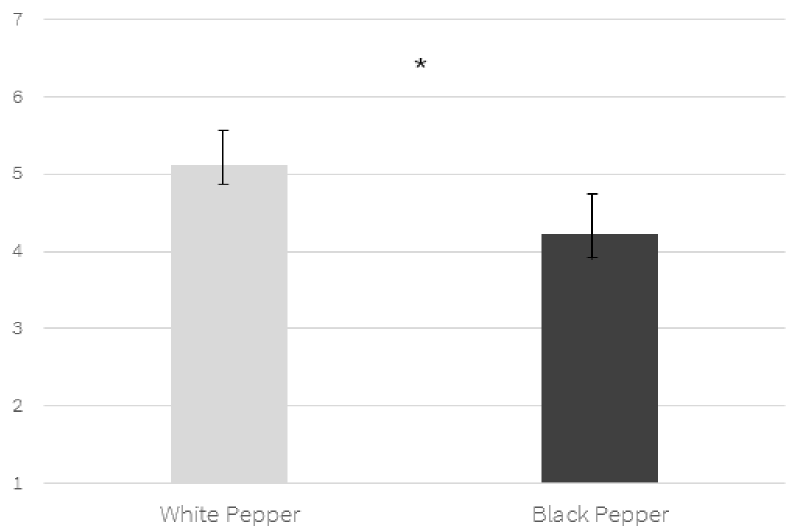

Figure 3. Product Evaluation

5. Limitations

In this study, only one type of humanoid robots (Pepper) [6] was used. Recently, however, not only humanoid but also product type robots such as Echo, developed by Amazon [28], and robots positioned between humanoid and product type robots such as JIBO [7] have been developed. The appearance of the robots and robot colors affect user expectation of the role and classification of the robot. In further studies, we will attempt to further categorize robot appearance, color, and roles.

Further, the participant pool in this study was limited. Participants with more diverse cultural and educational backgrounds will enable further generalization of findings. We will address these limitations in future studies.

6. Conclusion

In this study, we investigated how users classified robot roles based on the color of the robot. When the robot was white, participants classified the robot closer to white appliances than brown ones, and when the robot was black, the participants classified the robot closer to brown appliances than white ones although the actual Pepper was white and the actual work of Pepper is close to brown appliances [6]. Participants rated appropriateness of the robot color. According to the result, in the case of the humanoid, white is more suitable for the robot than black. In addition, we examined whether the color of the robot affected product evaluation. The results showed that participants preferred the white robot over the black robot. The above results indicate that people expect a humanoid robot to perform more household work when the robot is white in color than when the robot is black in color. Conversely, when the robot is black in color rather than white, it is more often expected that the robot will provide entertainment. And also, the results imply that people feel more positive to the robots with appropriate colors. Finally, humanoid robots are more positively accepted by users when performing housework than when providing entertainment. Thus, we suggest that the color of the robot should be selected according to the role of the robot, and humanoid robot designers and engineers develop the robot in bright colors and categorize it as white goods which assist in household work.

Acknowledgments

This work was supported by the Technology Innovation Program (10077553, Development of Social Robot Intelligence for Social Human-Robot Interaction of Service Robots) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea).

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