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Maintaining Learning Motivation of Older People by Combining Household Appliance with a Communication Robot

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***Abstract*—Today's household appliances are quickly increasing their features and functions. These new technologies require innovative training methods to maintain learning motivation especially with older users, because they may need more time to learn. Conventional manuals are insufficient to maintain motivation in this population. Previously studied assistive communication robots also have difficulty explaining a second device because their strong presence distracts the user from the device during explanation. We propose an anthropomorphized learning method that sustains older people's motivations to learn new technologies. Our method creates an anthropomorphized household appliance using robot eyes and arms. This method assists the learning process using human expressions. These human-like expressions attract users during training and maintain learning motivation. Our system uses three forms of anthropomorphization: pointing, directive motion, and emotion. We designed and implemented both hardware and software and evaluated the method by training older people to learn a vacuum's features. Our method increased older people's emotional status by an average of 2.53 points compared with the manual learning that decreased emotional status by -.53. This increased emotional status suggests that our system could maintain older users' motivation more effectively compared with traditional manual methods.**

I. Introduction

The rapid development and growth of new technologies over the past century have yielded an array of features and functions that have been incorporated into household appliances to make life easier. These enhancements to appliances have been designed to do everything from saving time, reducing the need for human labor, matching specific household needs (e.g., different cycles and water temperatures in a washing machine to clean more types of fabrics), and overall enhancing quality of life. Yet some of these features go unused, and the latest features or changes to appliances may require more time from consumers, especially older adults, to learn how to use them [1] (we defines the people who are more than 60 years old as older people in this paper). Difficulty learning new features deprives many users of all ages the chance to benefit from the enhanced features.

Fig. 1. Anthropomorphized learning method

Several challenges exist in the effort to help older people understand how to use sophisticated household appliances. A universal design approach simplifies the functions of household appliances to make them easily understood by all users. Simplified manuals and handbooks are well-known methods to explain important functions [2].

However, the above solutions are not fundamental for older people, because these methods neglect the problem of maintaining their motivation through longer learning periods. A simplified interface does not necessarily mean an improved interface, as some additional and important functions may be less apparent. Universal design also forces a compromise for all user groups with sacrifice of its additional functions. Further, simplified handbooks do not inform people about all of a device's functions.

We propose to use anthropomorphized learning methods to solve the aforementioned deficits in conventional learning. Our training method uses human-like wireless robotic eyes and arms in addition to voice instructions as an alternative for conventional manuals. These robotic parts directly anthropomorphize the look of a device and are also used for self-explanation (shown in Fig. 1). The anthropomorphization improves the learning motivation of all people because the human-like representation through appearance, gestures, emotions, social manners, and conceptual metaphors are innate for the user [3]. We can apply human-robot interaction to explain features naturally and encourage older people during training with anthropomorphization. These robotic parts also have several advantages compared with conventional service robots. For example, these robotic parts do not take up more space and are less expensive than an independent robot.

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The remainder of this paper is organized as follows. Section 2 describes the obstacles for older people's learning and discusses how anthropomorphic expression supports motivation for learning compared with a traditional manual and instructional robots. Section 3 explains the three goals achieved by an anthropomorphized learning method. Section 4 describes the implementation of each humanoid part (eye-like parts and arm-like parts). Section 5 describes the methods to evaluate it. Section 6 presents results from the experiment and these results are discussed in Section 7. Last, Section 8 concludes the paper with a summary of our results.

II. Comparing Conventional Methods of Human Factors for Older People

Two pieces of evidence suggest that conventional learning methods like manuals or guided instructions are not sufficient to support older people's learning process. The first is that even if learning capacity is not decreased, older people require more learning time than younger people. The second is that the presence of external helpers during the learning process results in a loss of motivation for older people [4-6].

A. Sustaining longer learning time

When studying something sequentially, older people score comparably with younger people [4]. However older people are not as good at learning two or more things in parallel [5]. This research implies that if we inform older people about information sequentially and interactively, they can learn the same amount of knowledge even if the learning process takes more time. Other research shows that when users are required to recall knowledge from semantic memory, both older and younger people have sufficient recall [6]. However recollection time becomes longer in older people.

The above evidence suggests that older people require more time for learning. As training times become longer, the task has to be more attractive or enjoyable to keep user's learning motivation. Traditional manuals are not helpful to sustain older people's motivation. All information is written in parallel and not provided to users interactively (Fig. 2 A).

B. Avoiding powerlessness during learning process

Studies on locus of control in older people show that as we age, our internal scale (the magnitude of one's belief that they control their life) declines and the external scales (the magnitude of one's belief that their environment controls their decisions and their life, like powerful others and chance) increase [7-8]. This result demonstrates that older people are more sensitive about interference by others during the learning process. Rogers suggests older people can get caught in a negative cycle wherein they see some decline in their abilities and the process makes them feel powerless [1]. He noted that when they believe they need more help from others, they avoid intellectually demanding tasks. This results in further decline of their abilities. As a result, they avoid tasks that make them feel powerless, and so on.

This tendency to avoid a third person's explanation may suggest the reason why some older people reluctant to listen human helper's explanation. The tendency also suggests that conventional robots and virtual agents are not helpful for the

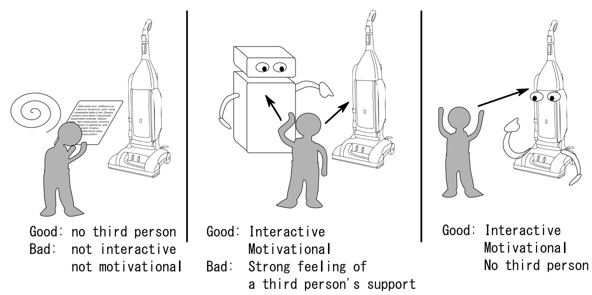

Fig. 2. Conventional learning method: conventional manual (left), learning with supportive agents (middle), and Anthropomorphized learning method (right)

learning process (Fig. 2 B). Several studies have tried to use robotic companions for older people [9-11]. When these robots interact with people directly, their social presence increases people's motivation for interaction. However, when they explain information about another object, these robots behave as third persons for the users. Our previous studies suggest that the external supportive agents like humanoid robots divert the user's attention away from the training [12]. There is the dilemma that even if we improve a robot and make it attractive, the attractiveness itself becomes an obstacle to learning. The dilemma becomes larger when the robot and individual cannot sustain interaction over time. For example, the presence of a robot does not increase learning when the robot explains features of appliances to anonymous users in the store or in a public space. Kanda et al. noted that without keeping a relationship with users, robots do not influence training in field experiments [13].

C. Solution

We propose an anthropomorphized learning method to solve the two problems discussed above. This method uses robotic human-like parts instead of conventional independent robots and makes the target into a social robot directly. Figure 2 C shows how our method achieves explanation to older people. The anthropomorphized learning method provides interactive and step-by-step learning similar to communication robots or virtual agents. Instead of explanation by a third-person, our method converts the target object into an instructor directly. Our approach minimizes the feeling of older people that a third-person is supporting the learning process [12][14]. This decreases the risk that older people will have a negative experience in the learning process. Anthropomorphic features in the real world have advantages to pointing another real world objects[15-16].

III. Anthropomorphized Expressions

The anthropomorphized learning method converts the technology to be learned into the communication robot with robotic eye-and-arm-like parts and can provide human-like representations for any object. These representations add several human-like expressions to the training. Their expressions supply the users with clues to understand each feature more than they would by using a conventional representation in a manual. In this section, we categorized three expressions that are achieved by our method.

A. Pointing gestures

Pointing gestures are fundamental in human-human communication [3] and are also used in human-robot interaction [17]. These gestures make it possible to describe each feature's location directly.

We use two pointing gestures called spot pointing and region pointing in our method. When the robot wants to direct attention to accurate particular spot in its "body," where the hose detaches for example, the eyes and arms calculate the position of interest and direct the user there (Fig. 3 A). Alternatively, when the robot wants to bring attention to a broad region on its "body" like where the electrical cord is, the eyes point to the center of the region and the arm directs attention to the region using a waving gesture (Fig. 3 B).

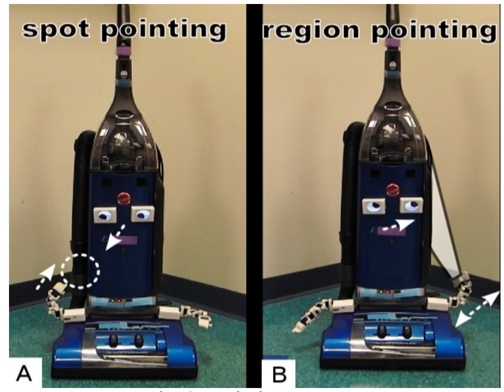

Fig. 3. Pointing gestures

B. Moving suggestions

Moving suggestions instruct users on how to manipulate the feature of the target spot or region. After pointing gestures, users attend to the target spot or region. Then, the arms invite users to mimic its actions using their movements. The eyes remain gazing at the target. Figure 4 shows an example of moving suggestion. When the user recognizes the target, here a power switch, from the gazing and pointing, the hands move in a vertical direction. The robot hand mimics the feature's required gesture and thus suggests how to move the switch and power the vacuum.

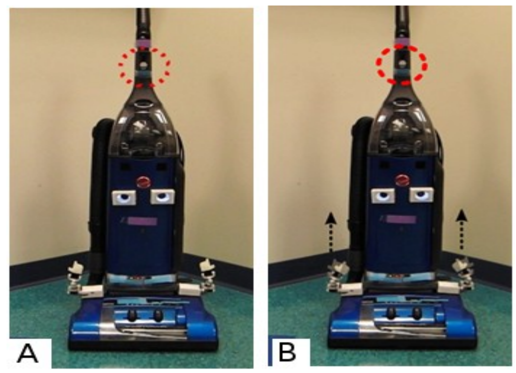

Fig. 4. Moving suggestion for power-on

C. Emotional representation

Anthropomorphization of the object also enables it to provide emotional representations. It allows the user to estimate the complex status of the household appliance. If the appliance displays a happy emotion, the user feels that they are doing well on the training (Fig. 5). It provides motivation for the users. If the machine shows a sad emotion, they think that there might be a problem with the vacuum. It also engenders the users' congeniality toward the household appliance. These emotional representations are very abstract. However, several studies find that although each emotion is abstracted, users are still able to understand the meaning of these emotions [18-19]. Several human-robot interaction and virtual agent studies tell us that emotional gestures evoke feelings of affability and increase motivation [20-21].

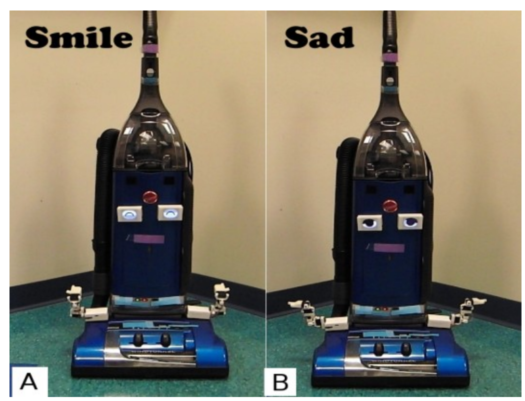

Fig. 5. Emotional representation

IV. Design and Implementation of Anthropomorphic Robotic Parts

Our system uses human-like robotic eyes and arms to build upon a conventional training manual using three anthropomorphic expressions noted in Section 3.

A. Hardware

Unlike many manipulation robots, our anthropomorphized objects do not need to manipulate other objects using their attached hands. Our robots are used only to direct and express emotion and must not disturb objects' tasks. These restrictions require simple and light devices so they can be easily attached without posing a problem. We developed small human-like robotic devices and attached them to our target by using hook and loop fasteners (Fig. 6). They are light and can attach anywhere.

The eye-like device consists of an OLED panel and has a pupil and eyebrows on it. The pupil is drawn as a circle. The eyebrow is drawn as an upper black region. They can be used to gaze in any direction as if the device could actually see and direct its gaze. The detail gazing algorithm is on our previous study [12].

The arm-like part consists of four servo motors. All motors are constructed by i-Sobot motors [22]. These motors can calculate precise pointing positions with the algorithm of invert kinematics. These motors can also perform several gestures including emotional gestures. The arms are covered with cloth to conceal the parts and avoid giving a machine-like impression.

Each part has its own battery and runs over 5 hours without

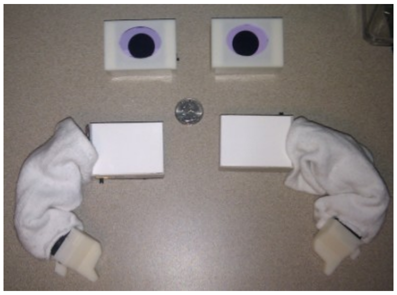

Fig. 6. Eye parts(59mm x 41mm x 21mm, 30g) and arm parts(185mm x 41mm x 30mm, 125g) photo. A United States Quarter is in the middle to demonstrate scale.

charge. Each device connects with a control terminal via Bluetooth.

B. Software

First, we configured the body by placing the anthropomorphizing features on specific locations. As the device we used did not have a body-like shape, we had to plan the placements to best imitate a robot. Figure 7 shows the entire design of our system. Unlike a conventional robot, our robot does not have a particular body shape but rather has a variable one.

We created an imaginary body image with a module called Body Image Creator. It uses marker-detection by ARToolKit for calculating positions of each part and pointing target [23]. Figure 8 shows how the body image was created.

Next, we loaded the manual of the targeted household appliance into the system. We configured the system to add pointing, gestures and emotional representations according to the locations of features. We generated a training scenario from a selection of sections from the original manufacturer's manual.

After these methods were applied, our anthropomorphized device robot behaved as a common communication robot. When users approached the target, our robot began to explain its features according to the communication scenario. A synthesized voice explained the device's features by reading text generated from the manual.

V. Methods

To evaluate how an anthropomorphized learning method sustains older people's motivation during the learning process, we created a task that older people might do at home: learning a new vacuum's features. We had older adults complete a self-guided training task to compare the motivation and emotional states of those learning from the user's manual and those learning from an anthropomorphized device.

A. Creating manual training and anthropomorphization training methods

As a target household appliance, we selected a vacuum that had many complex functions in it (Hoover Windtunnel [24]). This vacuum is equipped with five switches, three lights, two doors, six additional tools for cleaning. We thought that this vacuum was complex, yet simple enough for users to learn its features without help from the researchers during training.

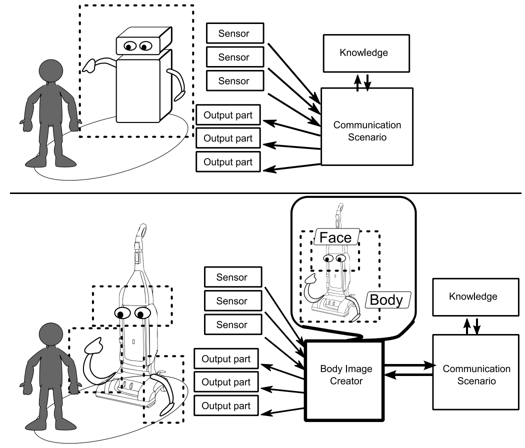

Fig. 7. Common communication robot design (above) and our robot design with a variable body image (below)

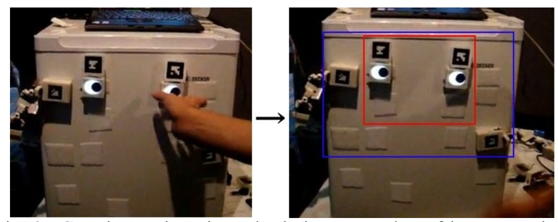

Fig. 8. Creating an imaginary body image on the refrigerator using marker-detection

We selected only seven sections of the original manufacturer's manual to create a simplified manual. The simplified manual was divided into seven sections and included 12 parts to explain the vacuum's features (Table 1). We created both an experimental and a control condition. In the experimental condition, the communication scenario of anthropomorphized vacuum is created from the simplified manual. In the control condition, a conventional manual book is created from simplified manual. As a first step, we used manual book method for control condition instead of human guided method. Because human guided method requires more cost for older people compared with manual method.

The communication scenario includes several expressions noted in Section 3. For example, the power switch location is detected either by looking at the diagram in the simplified manual or by following the gestures of the robotics parts in the other condition. The communication scenario also adds emotions to emphasize important points of the training. For example, when the material text noted that "vacuums can be difficult to maneuver", our anthropomorphized system creates a sad expression.

The voice is played on a speaker placed back of the vacuum. We found that the synthesized voice is not clear especially for older people in pre-experiment. We used a female voice that is processed more robotic and high-pitched, instead of using a computer-generated synthesized voice used on the normal system configuration. A recorded voice increased understanding and minimized pronunciation errors that computer-generated voices sometimes produce.

TABLE I
EXPLAINED FEATURES

Section (subsection)	Section name	feature
1 (1)	Power	Power on switch and cord
2 (2)	Positioning	Upright / Tilted
3-1 (3)	Adjustment	Floor surface
3-2 (4)	Adjustment	Carpet height
4-1 (5)	Cleaning Status	Dirt Finder
4-2 (6)	Cleaning Status	Dirt Finder sensitivity
5 (7)	Self-propel	Self propel switch
6-1 (8)	Additional tools	Locations of additional tools
6-2 (9)	Additional tools	Caution to make additional tools
7-1 (10)	Maintenance	Center lamp and a filter bag
7-2 (11)	Maintenance	Roller protect filter
7-3 (12)	Maintenance	Air cleaning filter

B. Participants

We collected data from training sessions with 30 American participants, aged 60 to 80 years old. All were English speakers. They were all able to operate household appliances. They did not have any neurological or cognitive disabilities. We divided the participants into two groups. Fifteen participants (6 males, aged 60 to 79 years old, average is 68.6 and standard deviation is 6.3) were assigned to the anthropomorphized (experimental) group and 15 participants (6 males, aged 60 to 79 years old, average is 66.1 and standard deviation is 7.2) were assigned to the manual (control) group. We created a 1.6m distance between the vacuum and the participant. Participants were seated on a rolling chair and were told they could move around the room as they liked.

C. Instruction toward participants

Upon arrival at the lab, participants completed a consent form and a questionnaire that included questions about their current emotional state. Then, participants entered the experimental room. The research assistant gave the following instructions to the participant:

"Please sit down here. Remember that if you want to move during the training, feel free to do so (by moving the chair). This training method has been created to make learning how to operate a new household technology easier. Please evaluate this system with keeping in mind that the system was designed to support the learning of all people. I'll ask you later about the training results. Imagine you have just purchased this new vacuum cleaner for your home and you want to learn how to use it."

After these instructions, participants in the experimental condition were given the instruction sheet that included nine commands. They then began the training. They interacted with the vacuum by asking it seven questions that corresponded to each section in Table 1. Two control commands ("next" and "repeat") were used to either move onto the next section or repeat a section they just heard. They were told they could ask the questions in any order they liked to complete all the training sections. These commands are recognized by voice recognition system in a normal system configuration. However, we used human experimenter to recognize a participant's voice in this experiment to avoid unwanted noise. Each question they asked was registered by an experimenter who pretended not to be involved in the training. This experimental setup is known as the Wizard of Oz method. The training in this condition included the recorded voice to explain the vacuum's features and robotic eyes and arms to gesture to areas of the vacuum and give feedback. When the explanation for a section finished, the system waited 3 seconds and required the next command. It would then suggest that participants ask a different question to go to another section, repeat the section they just heard, or move onto the next section listed on the instruction sheet. All utterances and gestures performed by the device during the experiment were conducted according to a determined script. Implemented 14 motions are created before the experiment and selected by hidden experimenter. The research assistant and the experimenter did not interact with the participant during the 30 minute self-guided training session.

Participants in the control condition were given the instruction sheet and the conventional manual. The manual included a written version of the same text that was given audibly in the experimental condition. The manual also included figures and pictures that highlighted the regions of interest for each section or function, instead of the gesturing used in the experimental condition. The figures were the same as those used in the commercial manual [24]. Participants in this condition learned all the vacuum's features using this manual.

For both conditions, all instructions were given by the research assistant. During the training phase, participants in both groups could move around the experimental room and manipulate the vacuum as they wanted. All participants were given 30 minutes to learn all the features of the vacuum, going at their own pace. They were told they could end the session at any time, but could only interact with the vacuum during the training.

When participants determined that the learning process was finished, they told the research assistant. Then, the research assistant asked the participant how they would clean the room and replace the filter bag. The participants were guided to another room to answer questionnaires that assessed their emotional state and how many functions they recalled. The final questionnaire was given to ask 14 questions about various vacuum functions they learned during the training. At the end of the experiment, participants received a $25 gift card to a bookstore and a debrief form.

D. Evaluation Method

Before and after the experiment, participants stated their current feelings on a 4-point Likert scale with 10 positive and 10 negative emotions presented in a random sequence (Table 2). The scales are based on 20 state values in State-Trait Anxiety Inventory (STAI) scales [25]. We calculated participants' total emotional score by adding positive values and subtracting negative values from them. We think that the total the sum of the emotional values are more accurate to estimate participant's emotional state compared with the independent emotional value.

TABLE II
EMOTIONAL STATES

positive	negative
I feel calm	I am tense
I feel secure	I feel strained
I feel at ease	I feel upset
I feel satisfied	I am presently worrying over possible misfortunes
I feel comfortable	I feel frightened
I feel self-confident	I feel nervous
I am relaxed	I am jittery
I feel content	I feel indecisive
I feel steady	I am worried
I feel pleasant	I feel confused

Participants' motivation themselves are difficult to estimate. We afraid the direct questionnaire for their motivation influences their motivational state itself. We calculated participants' motivation during the training with this emotional score. Several researches shows the relation between emotional state and motivation [26-27]. When the emotional score was stable or increased after the learning process, we determined that their motivation was sustained. However, when their emotional score decreased after the experiment, we determined that they were not motivated during the learning process. We hypothesized that participants' emotional score would be higher in the experimental condition compared to the control condition.

VI. RESULTS

We compared each participant's emotional score before and after the experiment and calculated the difference of each score. We think that calculation of the difference will remove participants' long term emotional effect (like moods or situation before and after experiment). The average difference of emotional status for participants in the anthropomorphization method is 2.53. The average in manual method is -0.53. We conducted a t-test ($p<.05$) for both group's differences and found significant difference ($p=.037<.05$) (Fig. 9). The $p<.05$ based evaluation is well-known in human-robot interaction field [13]. The error bars on the figure show standard deviations.

We also evaluated how many features of the vacuum participants learned and were able to remember. The average number of learned functions in the anthropomorphized group is 10.36 compared with 9.87 in the manual group. However, there is not a significant difference between these two groups ($p=.58>.05$). The participants also answered how interesting and difficult the training was on a 10- point Likert scale. The mean interest score is 6.8 in the anthropomorphized condition and 5.0 in the manual condition. We applied t-test and there found a significant difference between the two groups for this measure ($p=.096<.10$). The average difficulty score is 3.17 in the anthropomorphized condition and 3.08 in the manual condition. There is no significant difference between these two groups for this measure ($p=.92>.10$).

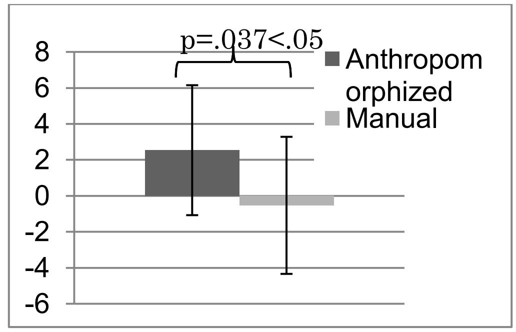

Fig. 9. Changes about emotional score in experimental group (anthropomorphized learning) and control group (manual method)

VII. DISCUSSION

A. Relationship between motivation and remembered features

The significant differences in emotional state (motivation) and interest scores between the experimental group and the control group suggest that our training method is more enjoyable than conventional manual method. This result supports our hypothesis that an anthropomorphized learning method better maintains older people's motivation during the learning process compared to the conventional manual method.

However, there was no significant difference between conditions in the number of remembered features. We think this is due to the experimental situation itself that may have increased older people's attention during the training process. All participants noticed that this was an experiment. They also knew that they would get a gift card after the experiment. Their perception of the experimental environment and of the incentive for participating could have increased their attention.

In our experiment, the difference of motivation did not appear to influence remembered features directly. We still need to find more appropriate evaluation method to search what is happened in the participants during anthropomorphized training. However, we think that motivation becomes more of a problem in the real world because they are not being observed and there are no rewards to increase their attention. Our previous experiment shows that when the participants did not realize they were in an experimental environment, they showed different learned scores [12].

B. Difficulty of both training methods

We could not find significant differences between groups on the difficulty of task measure. This finding could have appeared for three reasons.

First, there were within group differences in both experimental conditions. Some participants had experience using a vacuum and others did not. We think that their various individual differences and experiences could have impacted the learning process. To collect more precise data, we need to categorize participants' background with vacuums and compare groups with different experience using the device.

Second, there were the differences in their abilities to manipulate objects. Some of the instructions instructed them to manipulate the target directly (e.g. plug the cord into the electrical outlet). However, two people in the experimental group complained that the vacuum was too heavy to maneuver. These unwanted difficulties in the task may have increased the difficulty of the experimental training method.

Last, our method did not always provide complete explanations. Six participants in the anthropomorphized group did not hear the full explanations during the interaction. Four of the training sections included sub-parts that had to be reached by the participant directing the training to the next part of the section. However, six participants did not use the correct command to continue to the next part of the section. Thus, they missed some parts of the training. One participant noted on the questionnaire that the voice interaction seemed too automatic. We think that this incompleteness of verbal interaction increased the difficulty of our anthropomorphized learning method and hampered the participants' ability to learn all the features of the vacuum. However, we think that future studies can resolve this issue by using several human robot interaction methods, like different communication responses and conversational fillers [28]. In future work, we want to survey long-term effect of anthropomorphization. Our study shows the advantage of anthropomorphization. However, our study doesn't show how many anthropomorphic features are required to anthropomorphization of users. We also need to research appropriate anthropomorphic design for avoiding excessive complexity. Our implementation in this study is quite simple to be called as interactive. We also want to improve our interaction using communication robot technologies. We also want to evaluate other user's states influenced by anthropomorphization like co-presence.

VIII. CONCLUSION

We propose an anthropomorphized learning method for older people to maintain their motivation while learning how to use a new device. Our robot anthropomorphizes the shape of an object using human-like eyes and arms and uses a recorded voice along with gestures and expressions to explain how to use the device. The anthropomorphization method provides an interactive explanation without a third-person. It assists in the learning process of older people using native human expressions like pointing, gestures, and emotions. We developed the robot for the anthropomorphized learning method and evaluated our method with an experiment of older people. The result showed that our system increased older people's emotional state after the experiment compared with a manual method. These results suggest that our method can sustain older people's motivation during learning, compared with a conventional manual method.

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