# Do Elderly People Prefer a Conversational Humanoid as a Shopping Assistant Partner in Supermarkets?

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## ABSTRACT

Assistive robots can be perceived in two main ways: tools or partners. In past research, assistive robots that offer physical assistance for the elderly are often designed in the context of a tool metaphor. This paper investigates the effect of two design considerations for assistive robots in a partner metaphor: *conversation* and *robot-type*. The former factor is concerned with whether robots should converse with people even if the conversation is not germane for completing the task. The latter factor is concerned with whether people prefer a communication/function oriented design for assistive robots. To test these design considerations, we selected a shopping assistance situation where a robot carries a shopping basket for elderly people, which is one typical scenario used for assistive robots. A field experiment was conducted in a real supermarket in Japan where 24 elderly participants shopped with robots. The experimental results revealed that they prefer a conversational humanoid as a shopping assistant partner.

## Categories and Subject Descriptors

H.5.2 **[Information Interfaces and Presentation]**: User Interfaces-Interaction styles

## General Terms

Design, Experimentation, Human factors

## Keywords

Communication robots, Robots for elderly, Field experiments

## 1. INTRODUCTION

In many developed countries, including Japan, Italy, and Germany, the ratio of senior citizens continues to increase. Societies are facing insufficient people to assist the elderly. Studies on assistive robots include helping the elderly and the disabled. Robots can provide such physical assistance as walking aids [6, 11], and carrying baggage [17].

HRI has two views toward robots: tools and partners [2]. In the tool view, robots are expected to reliably provide services based on human commands. Assistive robots that offer physical assistance are often considered tools in many contexts. In a partner view (peer [7] or companion [4]), robots provide companionship in a trusted relationship [10] and expected to initiate interaction and other services on its own. For example, robots have acted as guides at an expo [25], and a museum [3].. The key point of the deference between tools and partners are whether they have a function to establish a friendly relationship with interacting people. For example, with a shopping robot, functions such as a chatting ability or having a human-like appearance are not directly related to the main task, but these futures can contribute to establish/enhance the friendly relationships.

Figure 1. Shopping with a robot

Are there any contexts where a partner metaphor fits assistive robots better for physical assistance? In such a context, what would people require for the robot to be equipped with? This study aims to answer these questions. To address the first question, we used a situation where robots were used like tools, but if a human companion provides the same service, he/she would be thought of a partner, not a tool. We selected a shopping assistance situation where a robot helps an elderly person by carrying a shopping basket (Figure 1). This is one typical scenario used for assistive robots in past studies [9, 17].

The second question is the design consideration for assistive robots in a partner metaphor, which is our main research question in this paper. Assuming a context where a physical assistive robots is a better fit with a partner metaphor, what is the crucial design consideration? Comparing previous studies of social robots that provide companionship [12] and assistive robots that provide physical assistance [6, 11], the major differences in the robot design can be summarized as two factors: *conversation* and *robot-type*.

The first design factor concerns whether robots should have conversations with people. They might be expected to give

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commands by spoken dialogue. But in a context where conversation is superfluous to complete the task, is it still valuable for social reasons? If we choose the partner metaphor, having a conversation is natural. Human beings talk anywhere. In contrast, if we choose a tool metaphor, having a conversation is nonsense.

The second design factor concerns the robot-type. For applications of shopping assistant robots, a cart type is a simple design that satisfies the functional requirement [1, 17]. Within a tool metaphor, maybe this *simple is best* solution is true. In contrast, if the robot is perceived as a partner, is a functionally simple design the best? Conversational robots are often designed as humanoid types [12, 18]. If an assistant robot having a conversation is perceived as a partner, people might prefer a humanoid type robot. This paper addresses the effect of these design factors.

## 2. Related Works

### 2.1 Assistive robots for the elderly

A tool metaphor is often considered for assistive robots that offer physical assistance for the elderly. For example, researchers have developed robots as walking aids [6, 11]. Mutlu et al. developed a conveyance robot to assist hospital staffs, which is an indirect assistance for senior citizens [21].

A partner metaphor is recently being considered for social robots for health assistances by such conversations as reminders of medicine schedules [20, 22]. Therapy purposes are another point of view with a partner metaphor; for example, a seal robot was used for robot therapy [23].

However, it remains unknown whether the elderly prefer a partner or a tool metaphor in situations where robots are used like a tool and a human partner could do the same service, e.g., shopping assistance. Moreover, past researches did not focus on the effect of the appearance differences of robots. Therefore, we experimentally tested our design considerations to determine whether the elderly prefer a conversational humanoid in this context.

### 2.2 Shopping assistant robots

Recent studies in social robots have started to develop shopping assistant robots in realistic environments. Considering a realistic shopping context, the researchers developed two functions: providing information and performing a physical assistance task.

Providing information such as route guidance is a common assistance in realistic contexts, particularly in large, complex shopping malls. For example, Gross et al. developed a shopping guide robot named TOOMAS that performs dialogue-based assistance by providing place and price information to shoppers [12]. Such robot has a function to greet people, which would be partner-directed design, while most of other function is purely for assisting customer as tool-directed design; but they did not provide any physical assistance.

Such a physical assistance task during shopping as conveying a shopping basket is a particularly useful service for the elderly [9, 17]. These robots physically assisted people in realistic environments; they can also be used to assist the elderly. The robots would be considered a tool, so they did not have conversations.

However, these robots did not focus on conversational interaction with people during such physical assistance tasks. Moreover, there was no discussion about the appearance effect of a robot that physically assists the elderly by having conversations.

## 3. Robot for shopping assistance

We designed a scenario for a shopping assistance service that can be implemented in the near future with a fully autonomous system. We used a Wizard-of-Oz technique to provide the service.

### 3.1 Robot

We prepared two types of robots: a *humanoid robot* and a *cart robot*. The major difference is their appearances; both have equivalent capabilities to perform shopping assistant (details are in Section 3.2): carrying a basket and engaging in conversations.

The *humanoid robot* is based on our communication-oriented design, whose purpose facilitates communication by eliciting anthropomorphic expectations toward the robot, which is based on Robovie II (Figure 2(a)) [15]. Our *humanoid robot* has a human-like appearance with two arms (4*2 DOF), a head (3 DOF), and is 120 cm tall. It has cameras and a speaker on its head. An external speaker is attached to the back of its body. A microphone is attached to the pole. It holds the basket by its arm and makes such gestures when it isn't holding a shopping basket.

The *cart robot* (Figure 2(b)), which is based on our function-oriented design, satisfies the required functionality to accomplish the tasks without any additional elements. It follows a *simple is best* principle. It is 85 cm tall and has a camera on a pan-tilt base. It has a speaker, a microphone on its front, and an external speaker on its back.

Both robots can carry a basket up to 5 kg. For the *cart robot*, the basket location was based on ease of use; its top is at 100 cm. On the other hand, the *humanoid robot* was designed to let its arm hold the basket. Access is not as simple as the *cart robot*, because the basket's height is relatively low, and its top is at 46 cm.

Both robots share other features. Speech synthesis software, XIMERA [16], was used for conversations. The microphone location was different, but the operators could equally listen to the users. Their mobile base is Pioneer3DX, which was used with the settings of the maximum forward speed, 750 mm/sec, and the max rotation speed, 100 degree/sec. A laser range finder and bumpers were attached to the mobile base for safety.

(a) Robovie (b) Cart robot

**Figure 2. Robots**

## 3.2 Shopping assistance service

Carrying a shopping basket is the primary task. In addition, a short conversation was designed to fit the following scenario.

### *3.2.1 Shopping behavior in a supermarket*

Figure 3 shows the supermarket where we conducted our experiment. Its area was around 2,350 $m^2$. Typically, people enter the building (Figure 3(a)), grab a shopping basket or a cart (b), and go to the supermarket. They often go to the main outer corridor (through areas c-i), and the center corridor (j). Finally, they reach the cash register (k), pack their items (l), and exit (a). On average, it takes about 15 minutes for elderly people to enter the supermarket and reach the cash register.

### *3.2.2 Service flow*

Based on the above observation, we designed a carrying service that starts when a robot meets a user at the building entrance (Figure 3(a)). When she arrives, the robot starts to follow her for shopping assistance. If its conversation function is enabled, it greets her (conversation function was only enabled in a *with-conversation* condition (Section 4.2)).

At the supermarket entrance (Figure 3(b)), the robot waits for her to set a shopping basket on it. After that, she freely walks around the supermarket, approaching shelves, selecting items, and putting them in the basket carried by the robot, who continues to follow her while she walks and stops beside her when she stops. If its conversation function is enabled, the robot talks to her as following the pre-defined rules (details shown in 3.2.3). For safety precautions, the robot was unable to go into a few areas of the supermarket. When she enters them, the robot waits for her.

When she arrives at the cash register, she unloads the basket from the robot, pays for and packs her items, and gives the bag to the robot. The robot follows her until she arrives at the exit of the building, which is about 50 m away from the cash register. If its conversation function is enabled, it says “Goodbye.”

### *3.2.3 Conversation during shopping assistance*

We designed a simple chat function. There are three types of triggers to make the robot speak. In the experiment, this function was only enabled in a *with-conversation* condition (Section 4.2).

**Location** We separated the supermarket into 12 areas (Figure 3). When the robot (and a user) moved into a new area in the supermarket (b-i in Figure 3), it initiates a short random conversation; e.g., where fish are sold (area f), it says, “Oh, here are fishes. I wish I could swim like a fish. Once I asked to my boss whether I can try to swim, but he said no.”

For each location, the robot has a few additional keywords for

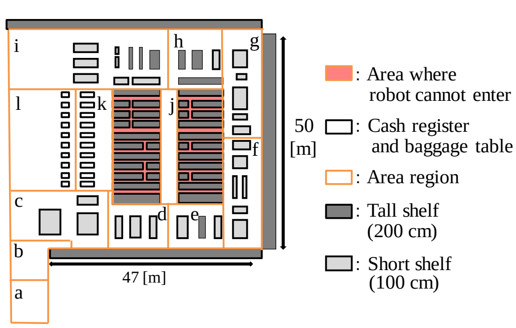



**Figure 3. Supermarket map**

responses. It accepts within 20 seconds after it says the above sentences. For example, if the robot asks, “What are you shopping for today?”, “vegetables” is listed in this keyword set. If a user says “vegetables,” the robot replies “Cool, it sounds delicious."

**When a user puts an item in the basket** The robot briefly comments when the user puts items in the basket, without really identifying them. It provides positive phrases based on the location; e. g., in an area where vegetables are sold, it says, “That looks delicious!”

**Response** Users are allowed to talk to the robot any time. Through preliminary trials we retrieved fourteen keywords that are often spoken to the robot and to which it is designed to respond. For each keyword, it makes a simple response. For instance, when a user says, “come here,” it responds with “I'm coming.” It responds to “Can you take this for me?” by saying, “No problem.” It makes vague responses to other utterance inputs, saying “oh really” and “ah-ha.”

Note that since we intend to identify the effect of conversation regardless of the requirement for providing the service, none of the above conversations are related to the functionality of the carrying service, and we did not include voice-based commands.

## 3.3 Software and operator’s involvement

Our near future vision includes the operation of the fully autonomously robot described in the previous section; but since our goal is to conduct a field experiment to confirm whether our design choice improves the acceptance of robots by the elderly, we prepared a semi-autonomous system.

### *3.3.1 Software architecture*

There are mainly three functions involved in this study: localization, navigation, and dialogue management. Figure 4 shows the software architecture that illustrates the relationship among these functions. All are partially operated by an operator.

**Localization** The robot tracks its position by using the wheel encoders. Although more accurate localization with laser range finders is a common technique [19] and would probably work well in this environment, we haven’t implemented it yet. Instead, the operator localizes the robot when its position greatly diverges.

**Navigation** The operator navigated the robot to follow the user (Section 3.3.2 explains the details). Safety is secured by an autonomous system. The robot’s speed is autonomously limited based on the distance between the robot and the nearest obstacle. For instance, when there are no obstacles within 1.65 m in front of the robot, it uses a top speed of 750 mm/sec. The speed is decreased based on the distance to the nearest object. If the distance is less than 0.45 m, the robot stops.

**Dialogue management** All utterance contents, which are prepared in advance, are associated with the three triggers shown in Section 3.2.3. When a human operator activates a trigger, the robot

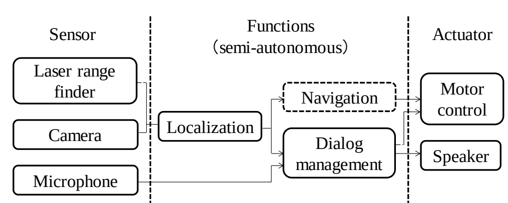



**Figure 4. Software architecture**

automatically chooses an appropriate utterance. For instance, when the robot enters a new area, a pop-up message appears on the interface window; it elicits the operator to order the robot to say a location-based utterance, which the robot generates.

#### *3.3.2 Tele-operation user interface*

Figure 5 shows a user interface for tele-operation. The primary information sources are the images from the camera (Figure 5(1)), a map showing readings from a laser range finder (Figure 5(2)), and sounds from the microphone. The operator uses all of this information to localize the robot, to identify or search for the user to navigate the robot for following. The robot autonomously stops before hitting an object. But it does not generate a path that avoids objects, so the operator decides the robot's path.

Figure 5(3) is a panel that activates a trigger to make the robot speak. The operator follows the rule in Section 3.2.3. When he hears a word, he chooses the heard word from the panel. When the robot enters a new area, he informs this through this panel so that the robot starts to speak. Similarly, when a user puts an item in the basket, he activates a trigger for it.

## 4. FIELD EXPERIMENT

A field experiment was conducted in a real supermarket where senior citizens shopped with the robot.

### 4.1 Participants

24 senior citizens (12 men and 12 women, who averaged 67.2 years old, s. d. 4.97) participated in our experiment. They are native speakers of Japanese who had never interacted with our robots before. They were paid 4,000 yen (47$) for each session, for a total 16,000 yen (188$) for the four sessions; note that since the shopping was real, they paid for their own groceries.

### 4.2 Conditions

We conducted a 2x2 within-participants factorial design with two factors: *conversation* and *robot-type*.

**Conversation factor**

*With-conversation* condition: robot's conversation function (described in Section 3.2.3) was enabled.

*Without-conversation* condition: conversation function was disabled. The robot did not say anything during the experiment.

**Robot-type factor**

Either a *humanoid robot* or *cart robot* was used (details are described in Section 3.1).

In all conditions, the operator controlled the robot based on the same rules described in Section 3.3, and we made sure that the operator can do equivalent controls in both types of robots.

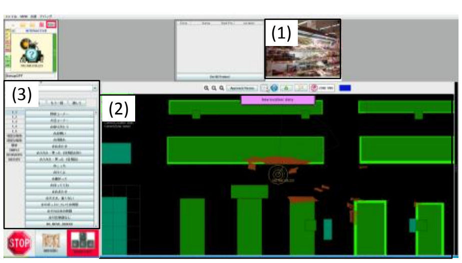



**Figure 5. Tele-operation user interface**

### 4.3 Experiment procedure

The experiment was conducted in a shopping mall with a supermarket. During the experiment, participants moved around and select items freely. The robot followed the participants except situations where they enter the narrow corridors (Figure 3) or the robot lost the participants. In the situations, the robot stops and waits until she/he comes back. Each experimental session was scheduled in the daytime on weekdays to avoid extra crowds, possibly caused by the robot.

Before the first session, the participants were given a brief description of the purpose and procedure of the experiment. Since this had a within-participant design, each participant participated in four sessions, mostly scheduled a series of continuous four days. The participants were notified in advance of the day and time schedule of the experimentation, so they have enough time to think what they will buy, as they would do in their everyday life. At the beginning of each session, we told them whether the robot can speak, confirmed the areas which the robot cannot enter, and explained how to hang the shopping basket on the robot. Then they went shopping with a robot that provided the service described in Section 3.2. They filled out questionnaires after each session; i.e. after using each kind of robot.

At the end of the fourth session, we did short interviews. Finally, we did debriefing, in which we explained the existence of the operator, only one participant mentioned that he had already guessed the operator's existence; it seems others were not surprised. The order of these conditions was counterbalanced. Staff remained around the robot for safety and recording videos.

### 4.4 Measurement

We measured *intention to use* because in studies of the acceptance of new technologies [5] and social robots [18, 26], it is modeled and indicates social acceptance.

1. *Intention to use*: three items were adapted from the study of Heerink et al. [13], including, "I'm planning to use this robot for the next few days." Cronbach's α was 0.936.

We also measured *perceived enjoyment* and *perceived ease of use*, since these concepts are considered the source of *intention to use*. The model of social acceptance [13] is illustrated in Figure 6.

2. *Perceived enjoyment*: five items were adapted from [13], including, "I enjoyed shopping with this robot." Cronbach's α was 0.916.
3. *Perceived ease of use*: six items were adapted from the study of Davis [5], including, "I found it easy to get this robot to do what I want it to do." Cronbach's α was 0.928.

All questionnaire items were evaluated on a 1-to-7 point scale.

### 4.5 Hypothesis and prediction

Our hypothesis is that a robot with a *partner* design is preferred for social acceptance, even for physical assistance tasks. Thus we made the following predictions:

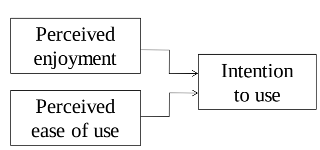



**Figure 6. Model of social acceptance defined by Heerink et al.**

Prediction 1: a *with-conversation* robot will be rated high in terms of *intention to use*.

Prediction 2: a *humanoid robot* will be rated higher than a *cart robot* in terms of *intention to use*.

## 5. Results

### 5.1 Verification of predictions

Figure 7 shows the scale results for *intention to use.* For the *intention to use* scale, we conducted a two-way repeated-measure ANOVA with two within-subject factors: *conversation* and *robot-type*. A significant main effect was revealed in both the *conversation* factor ($F(1,23)=12.74$, $p=.002$, partial $\eta^2=.356$) and the *robot-type* factor ($F(1,23)=4.36$, $p=.048$, partial $\eta^2=.159$). No significance was found in the interaction within these factors ($F(1,23)=1.83$, $p=.189$, partial $\eta^2=.074$). This means that both *with-conversation* and *humanoid robot type* significantly increased the social acceptance, measured by the *intention to use* scale. Our predictions are supported; we note that the result of the statistics did not change even if we eliminated the data of the participant who guessed the operator's existence during the experiment.

This result indicates that both *conversation* and *human-like robots* increased acceptance in a realistic shopping context.

### 5.2 Related scales to *intention to use*

We further analyzed *perceived enjoyment* (Figure 8(a)) and *perceived ease of use* (Figure 8(b)) and conducted a two-way repeated-measure ANOVA with two within-subject factors: *conversation* and *robot-type*. For the *perceived enjoyment* ratings, a significant main effect was revealed in both the *conversation* factor ($F(1,23)=27.39$, $p<.001$, partial $\eta^2=.544$) and the *robot-type* factor ($F(1,23)=5.24$, $p=.032$, partial $\eta^2=.186$). No significance was found in the interaction within these factors ($F(1,23)=0.01$, $p=.921$, partial $\eta^2=.000$). This means that both *with-conversation* and *humanoid robot type* significantly increased the *perceived enjoyment.*

For the *perceived ease of use* ratings, a significant trend was only revealed in the *conversation* factor ($F(1,23)=3.63$, $p=.069$, partial $\eta^2=.136$), and no significance was found in the *robot-type* factor ($F(1,23)=0.02$, $p=.889$, partial $\eta^2=.001$) or in the interaction within these factors ($F(1,23)=0.87$, $p= .362$, partial $\eta^2=.036$). The effect of the *conversation* factor is not conclusive, but *robot type* did not affect the *perceived ease of use*. These results are reasonable. We did not design *conversation* to assist the task. We expect the possibility that *humanoid robot type* might decrease the *perceived ease of use,* since its basket location was relatively less easy-to-access than the one in the *cart robot*; but no such

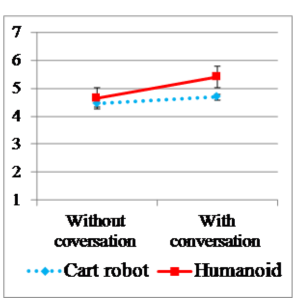



**Figure 7. Intention to use**

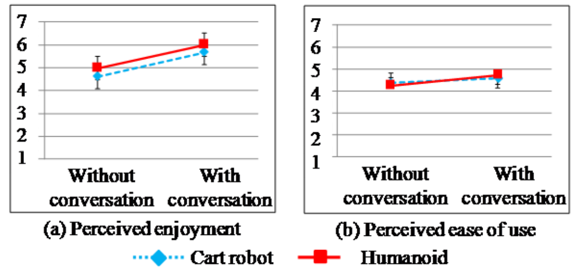



**Figure 8. Questionnaire result**

significant difference was reported.

In summary, both *conversation* and *humanoid robot type* improved *perceived enjoyment*, but no significant difference was observed among the conditions in the *perceived ease of use*. Considering the social acceptance model defined by Heerink [13], these results suggest that a significant improvement of *perceived enjoyment*, which is a part of the source of *intention to use*, is one major reason why *intention to use* significantly increased in the experiment. As verification of the predictions, we note that the result of the statistics did not change even if we eliminated the data of the participant who guessed the operator's existence during the experiment.

### 5.3 Why did robots provide different impressions?

As reported in Section 5.1, the *humanoid robot* and *conversation* conditions resulted in better social acceptance. We specifically asked why in a semi-structured interview conducted at the end of the experiments. We analyzed the interview results to investigate the reasons behind these different impressions.

#### *5.3.1 What was the benefit of conversation function?*

In the interviews, we asked the participants about their perceptions of the robot's conversation function to see whether they preferred it. Two coders analyzed and classified the transcribed results of interview from all 24 participants. The Cohen's kappa coefficient from the two coders' classifications was 0.931. They yielded the following classification.

(a) With conversation, they perceived that they are with or doing things with someone: one participant

(b) With its utterance or communicating with it, they perceived positive feelings (enjoyment, better feeling, and less loneliness): 13 participants

(c) Combination of (a) and (b): eight participants

(d) Its conversation function did not change their perceptions: two participants

This result confirmed our findings in Section 5.1 and 5.2 that conversation was connected to *enjoyment* and *social acceptance*, but hardly with *ease of use*. Note that nine participants mentioned the sense of "together with someone," which matches the partner metaphor.

#### *5.3.2 Why did a humanoid robot result in better social acceptance?*

We also asked participants about their perceptions of the robot type. As in the analysis in Section 5.3.1, two coders analyzed and classified the results. The Cohen's kappa coefficient from the two coders' classifications was 0.915. They yielded the following classification.

(a) With a *humanoid robot*, they perceived that they are together or are doing things with someone (or perceived a human-likeness in it): 16 participants

(b) Using a *cart robot* was easy because it was simple to put items in the basket (and *humanoid robot* was not easy to use): no participant, but combination with (a) is categorized as (c).

(c) Combination of (a) and (b): four participants

(d) Using the *humanoid robot* was difficult because it suggested a feeling of exploiting the robot: one participant

(e) Robot type did not change their perceptions: two participants

(e) Other answers: one participant

In Section 5.2, we found improvement of *enjoyment*, but participant articulations were more about a sense of "together with someone" rather than simple curiosity or impressions of novelty. Note also that although in category (b) they mentioned the ease of using the *cart robot*, it did not affect the averaged *perceived ease of use* or the overall social acceptance. This matches our concept of a partner metaphor rather than a function metaphor.

## 5.4 Is shopping with a robot different?

### 5.4.1 *Overall shopping behaviors*

First, we quantitatively compared the overall shopping behaviors among the conditions (Table 1) and measured the following three behaviors: *shopping route*, *shopping time*, and *number of purchases*.

For *shopping route*, we checked whether they went to the main corridor (outer corridor that goes through areas c to i in Figure 3) or into the area where the robot couldn't (Figure 3). Most people did both, and there were no significant differences among the conditions. Their *shopping time* was also similar, approximately 15 minutes. These behaviors are roughly the same as what we observed as shopping behaviors without robots (Section 3.2.1).

Small differences were found in *the number of purchases*, indicating that participants bought more items in the *with-conversation robot* ($F(1,23)=8.17$, $p=.009$, partial $\eta^2=.262$).

Overall, their shopping patterns resembled those without the robot and did not change among the conditions, although a small difference in the number of purchases was found (participants bought only one more in average in the *with-conversation robot*).

### 5.4.2 *Shopping with robot*

Here, we describe an interaction scene in one of shopping with the robot that was retrieved from an experimental session with an elderly male participant (hereinafter, referred as Mr. T) and a *humanoid* robot in the *conversation* condition. Figure 9 illustrates their behaviors, showing where they talked and when he put items in the basket. His shopping lasted 13.5 minutes.

Figure 10 shows a couple of interaction scenes. When they met, the robot greeted him (Figure 10(a)) saying, "Hello! I'm Robovie. Let's get a basket." After the greeting, Mr. T went to the basket area. The robot followed him and said, "Please hang your basket here," and gestured with its arm (Figure 10(b)). Then he started shopping; and the robot followed him and held the basket.

There were large individual differences whether participants talked to the robots. Mr. T was actively involved in verbal interaction. When the robot said, "Let's get a basket," he replied, "OK, let's go." When he put items into the basket (Figure 10(c)), he said, "Now I need some potatoes." After adding them, he said, "I need some fish next. Robovie replied, "That sounds good." He often talked to the robot when he put items in the basket and replied seven out of 12 times to the robot. For instance, when the robot entered area i, it initiated small talk:

Robovie: "We walked a lot today. I'm tired, but I really enjoyed it."

Mr. T: "I'm tired, too."

Robovie: "Well, but I could pass a lot of people, it was very interesting."

Finally, the robot said "goodbye" and Mr. T replied "goodbye" and waved to the robot at the exit (Figure 10(d)).

**Table 1 Shopping behavior in each condition**

| Robot-type | Cart robot | | Humanoid robot | |
|---|---|---|---|---|
| Conversation (with/without) | without | with | without | with |
| Enter main corridor | 21/24 | 21/24 | 19/24 | 21/24 |
| Into narrow space | 17/24 | 18/24 | 18/24 | 17/24 |
| Shopping time [minutes] (S. D.) | 12.44 (3.94) | 14.30 (4.99) | 12.63 (5,59) | 13.10 (4.57) |
| Number of purchases (S. D.) | 7.96 (2.91) | 9 (2.27) | 8 (2.18) | 9.25 (2.60) |

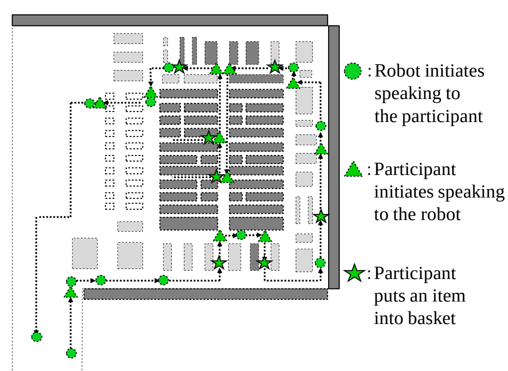
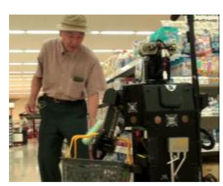


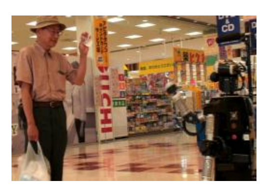

**Figure 9. Route and behaviors**

(a) Robot greets to participant

(b) Participant sets basket



(c) Participant adds item



(d) Goodbye

**Figure 10. Interaction scenes**

## 5.5 Summary of results

First, both *conversation* and *robot-type* factors significantly changed *intention to use*, which indicates social acceptance. Both factors contributed to improvement of *perceived enjoyment*, but they did not affect *perceived ease of use*. The results suggest that one main reason why *intention to use* significantly increased is the significant improvement of *perceived enjoyment* in the experiment.

The interview results highlighted that both *humanoid robot* and *conversation* provided a sense of "togetherness," which is one main reason they reported perception differences. We believe that this supports our partner metaphor for robots for assistive tasks.

# 6. Discussions

## 6.1 Design implications

One immediate design implication is that it is better for robots in a shopping mall for carrying services to have conversational humanoid characteristics. In reality, they involve cost considerations because humanoid robots usually cost more. We believe that robots in public environments would often be expected to have multiple functions, e.g., providing route direction as well as carrying a basket. For such purposes, a humanoid robot design would be financially beneficial, since a single robot can engage in multiple roles, and if available for a carrying service, it outperforms a simple cart robot.

Another important implication is that this study confirms the importance of enjoyment in a shopping support context. Its importance was previously found in social acceptance studies [13, 14]. This result suggests that when we think about human-robot interaction, not only its functional ease but also its enjoyment should be explicitly considered. Elderly people, who often suffer from social isolation, would particularly benefit from ubiquitous friendly conversation; since recently so many functionalities in our society are automated and lack a conversation.

## 6.2 Ethical consideration

Using robots often raises ethical concerns in various fields of application. Typical concerns about robots for the elderly argue that such use works against the elderly preference to receive services from humans and forces them to receive services from cold machines. Another concern is that the use of robots increases the already serious isolation of senior citizens from other people. These important issues must be considered.

On the other hand, in our society in the world, services are already being replaced by machines such as self-checkout. In some supermarkets, the elderly don't need to interact with people at all; they choose items from the shelf, put them in baskets, bring them to the self-payment register, and go home. For the application discussed in the paper, human services no longer exist, so having robots does not harm the elderly.

## 6.3 Can it be autonomous?

In this study, our robot was mostly teleoperated. Although this study indicates that robots were perceived as useful and accepted, it remains unclear whether such a robot can be autonomous in the near future. If it fails to gain autonomy and one human operator per one robot is always required, realistic deployment is difficult.

We discuss the possibility of automation for teleoperated techniques. Maybe the easiest function to automate is detecting user actions for putting items into the basket. This may be easily automated with either weight sensor or image processing.

Localization, which is recently maturing in robotics, may also be automated easily. SLAM studies have often demonstrated robust localization performance in complex environments. Moreover, we believe that with an adequate filtering technique, we can achieve localization in such crowded environments as supermarkets.

Robust tracking of users might be one of the difficult problems. Human tracking is often a focus of studies in robotics. Even though many techniques have been developed, yet due to occlusion in crowded environments a robot often loses a person. Maybe a combination with other identification techniques, such as RFID tags, should be considered. At least, a human operator might help situations where a robot lost the tracking; with this shared autonomy approach and with small efforts from human operators, robots could provide a carrying service.

Speech recognition is another difficulty in realistic environments, where the current speech recognition system has a success rate of only 21.3% [24]. This would be a critical problem if applications required voice-based commands; however, for the scope of this service, some recognition errors could be tolerated. Thus, it might be possible to automate the service with current techniques, or a semi-autonomous approach [8] could be used.

## 6.4 Limitations

The long-term goal of our study is to reveal the design considerations for the physical assistance for the elderly; but since this study was conducted for a carrying service at a supermarket in Japan, we cannot generalize about this design implication only from this study. We believe that it is useful to test the design considerations based on the partner metaphor in other contexts.

Even though this experiment was held in a realistic situation with participants who engaged in actual shopping, it was conducted within a framework of academic study. Participants only used the robots a few times. Thus, perhaps the effect shown in our experiment would be moderated if they were to get accustomed to the shopping assistant robots; i.e., the novelty effect was lost. As single study cannot reveal all; we were not able to extend the study to be realistic long-term study. This is one of the limitations of this study, which will be tested in the future, perhaps with the realistic deployment of robots in society.

# 7. CONCLUSION

This paper addresses a design consideration for assistance robots for the elderly. We tested whether the elderly accept a robot that is based on a *partner* metaphor in a typical basket-carrying service in a shopping context. We tested two factors: *robot type (a humanoid robot or a cart robot)* and *conversation*. We conducted a field experiment in a realistic shopping context with 24 senior citizens. The results revealed that the participants prefer a conversational humanoid as a shopping assistant partner; both *conversation* and *human-like robot* contributed to better acceptance. Qualitative data from interview indicates that *conversation* would provide positive feeling, and both *conversation* and *human-like robot* contributed to provide the sense of "together with someone". These results are consistent with the partner metaphor. We believe that our findings will lead to the development of assistive robots that act in realistic environments for elderly people.

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## 9. REFERENCES

[1] Bogdan, C., Green, A., Huettenrauch, H. and Severinson Eklundh, K. Cooperative Design of a Robotic Shopping Trolley. *In Proc. of COST-298 (European Cooperation in the Field of Scientific and Technical Research), 2009*

[2] Breazeal, C., Brooks, A., Gray, J., Hoffman, G. Kidd, C. Lee, H. Lieberman, J., Lockerd, A. and Mulanda, D. Humanoid Robots as Cooperative Partners for People. *International Journal of Humanoid Robots, vol. 1, no. 2, 2003*

[3] Burgard, W., Cremers, A. B, Fox, D., Hahnel, D., Lakemeyer, G., Schulz, D., Steiner, W., and Thrun, S. The Interactive Museum Tour-Guide Robot. *In Proc. National Conference on Artificial Intelligence (AAAI), 11-18, 1998*

[4] Dautenhahn, K., Walters, M. L., Woods, S., Koay, K. L., Nehaniv, C. L., Sisbot, E. A., Alami, R. and Siméon, T. How May I Serve You? A Robot Companion Approaching a Seated Person in a Helping Context. *ACM/IEEE Int. Conf. on Human-Robot Interaction, 172-179, 2006.*

[5] Davis, F. D. User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International Journal of Man-Machine Studies vol. 38, Issue 3, 475-487, 1993*

[6] Dubowsky, S. Genot, F., Godding, S., Kozono, H.,Skwersky, A., Yu, H. and Yu, L.S. PAMM: A Robotic Aid to the Elderly for Mobility Assistance and Monitoring: A "Helping-Hand" for the Elderly. *IEEE Intl. Conf. On Robotics and Automation: 570-576, 2000*

[7] Fong, T., Nourbakhsh, I. and Dautenhahn, K. A Survey of Socially Interactive Robots. *Robotics and Autonomous Systems, vol. 42, 143-166, 2003*

[8] Glas, D. F., Kanda, T., Ishiguro, H. and Hagita, N. Field trial for simultaneous teleoperation of mobile social robots. *ACM/IEEE Int. Conf. on Human robot interaction, 149-156, 2009*

[9] Goller M, Kerscher T, Ziegenmeyer M, Ronnau A, Zollner J M, and Dillmann R. Haptic Control for the Interactive Behavior Operated Shopping Trolley. *In Proc. of the New Frontiers in Human-Robot Interaction Workshop of the 2009 Convention on Artificial Intelligence and Simulation of Behaviour ,2009*

[10] Goodrich, M. A. and Schultz, A. C. Human-Robot Interaction: A Survey. *Foundations and Trends in Human, Computer Interaction, vol. 1, 203-275, 2007*

[11] Graf, B. An Adaptive Guidance System for Robotic Walking Aids. *Journal of Computing and Information Technology, vol. 17, no. 1, 109-120, 2009*

[12] Gross, H.-M., Boehme, H., Schroeter, Ch., Mueller, S., Koenig, A., Einhorn, E., Martin, Ch., Merten, M. and Bley, A. TOOMAS: interactive shopping guide robots in everyday use - final implementation and experiences from long-term field trials. *IEEE/RSJ Int. Conf. on Intelligent robots and systems,2005-2012, 2009*

[13] Heerink, M., Kröse, B.J.A., Evers, V., Wielinga, B. The Influence of Social Presence on Acceptance of a Companion Robot by Older People. *Journal of Physical Agents, vol. 2 no. 2, 33-40, 200*8

[14] Heerink, M., Kröse, B.J.A., Wielinga, B.J., Evers, V. Enjoyment, Intention to Use and Actual Use of a Conversational Robot by Elderly People. *ACM/IEEE Int. Conf. on Human-Robot Interaction, 113-120, 2008*

[15] Kanda, T. Ishiguro, H. Imai, M. and Ono, T. Development and Evaluation of Interactive Humanoid Robots. *Proceedings of the IEEE, vol. 92, no. 11, 1839-1850, 2004.*

[16] Kawai, H. Toda, T. Ni, J. Tsuzaki, M. and Tokuda, K. XIMERA: a new TTS from ATR based on corpus-based technologies. *5th ISCA Speech Synthesis Workshop, 179-184, 2004*

[17] Kulyukin, V., Gharpure, C. and Nicholson. J. RoboCart: Toward Robot- Assisted Navigation of Grocery Stores by the Visually Impaired, *IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, 2845-2850, 2005*

[18] Lee, M.K., Kielser, S. Forlizzi, J, Srinivasa, S. and Rybski, P. Gracefully Mitigating Breakdowns in Robotic Services. *ACM/IEEE Int. Conf. on Human-Robot Interaction, 203-210, 2010*

[19] Lingemann, K. Nuchter, A. Hertzberg, J. and Surmann, H. Highspeed laser localization for mobile robots, *Robotics and Autonomous Systems, vol. 51, 275-296, 2005*

[20] Montemerlo, M. Pineau, J. Roy, N. Thrun, S. and Varma, V. Experiences with a Mobile Robotic Guide for the Elderly. *Int. Conf. on Artificial Intelligence. Edmonton, Jul. 587-592, 2002*

[21] Mutlu, B. and Forlizzi, J. Robots in organizations: the role of workflow, social, and environmental factors in human-robot interaction, *ACM/IEEE Int. Conf. on Human robot interaction, 287-942, 2008*

[22] Pollack M., E. Intelligent technology for an aging population: The use of AI to assist elders with cognitive impairment. *The AI magazine vol. 26, no. 2, 9-24, 2005*

[23] Shibata, T. An overview of human interactive robots for psychological enrichment. *The proceedings of IEEE Vol. 92, no. 11, 1749-1758, 2004*

[24] Shiomi, M., Sakamoto, D., Kanda, T., Ishi, C. T., Ishiguro, H., Hagita, N. A Semi-autonomous Communication Robot -A Field Trial at a Train Station-. *ACM/IEEE Int. Conf. on Human-Robot Interaction, 303-310, 2008*

[25] Siegwart R., Arras K.O., Bouabdallah S., Burnier D., Froidevaux G., Greppin X., Jensen B., Lorotte A., Mayor L., Meisser M., Philippsen R., Piguet R., Ramel G., Terrien G., and Tomatis N. Robox at Expo.02: A Large-Scale Installation of Personal Robots. *Robotics and Autonomous Systems, vol. 42, issue 3-4, 203-222, March 2003*

[26] Weiss, A. Igelsbock, J. Tscheligi, M. Bauer, A. Kuhnlenz, K. Wollherr, D. and Buss, M. Robots Asking for Directions: The Willingness of Passers-by to Support Robots. *ACM/IEEE Int. Conf. on Human-Robot Interaction, 23-30, 2010*