Participatory Design and Early Deployment of DarumaTO-3 Social Robot

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Abstract. With the problem of ageing population increasingly prominent, the burden of families, caregivers and medical workers to take care of older adults will be heavier. Social exclusion and cognitive dysfunctions make things worse, especially in times of a pandemic. One of the most effective approaches to solve these problems can be technology, which application is often limited by the acceptance of the end user. We introduce a social robot, DarumaTO-3, whose appearance is inspired by a traditional Buddhist and Shinto doll called Daruma, and perform a preliminary test in which we hear the response from older adults. This paper describes this new robot prototype, and reports the feedback received from the early deployment with 44 Japanese older adults.

1 Introduction

In the everyday life of older adults, there is a problem of lack of communication and interaction. When living alone, they may face loneliness. The problem gets worse with age, due to inability to use technological devices and increasing degrees of dementia. Nursery homes provide assistance, but especially in large ones, nurses cannot provide company all the times, and organised activities are limited.

According to the Ministry of Health, Labour and Welfare of Japan, there are over 30,000 nursery homes spread across the territory, and an even higher number of day care facilities. These numbers are increasing year by year. In 2014, over 25% of the population was over 65 years old. In this context, there

This work was supported by Ministry of Internal Affairs and Communications (MIC) of Japan (Grant no. JPJ000595). Special thanks to Tohoku University for hosting the experiment.

F. Cavallo et al. (Eds.): ICSR 2022, LNAI 13818, pp. 550–559, 2022.
https://doi.org/10.1007/978-3-031-24670-8_49

is a growing need of socially assistive devices, and the potential market is of 30 million users. In Japan in particular, by the next 20 years one in every three people will be 65+ years old [1]. Especially, in the pandemic, the health and well being of old adult appears to be impacted critically. Many feasible solutions were proposed to ease this social problem while obtaining a better understanding of the human user [2]. Socially assistive robots are one possible tool that can be used to mitigate the loneliness and isolation of the old adult that was brought by the COVID-19 pandemic [3].

One of the most successful robots employed in nursery homes is the seal robot Paro. The authors Shibata and Wada (2011) [4] argue that robot therapy can relieve their stress as animal therapy does. We believe that Paro's strongest point is the smart and functional design, and the ease of use. On the other hand, Paro's limitations in the interaction (no capability of dialogue) show that there is more potential in the field. Our research is contained within e-ViTA [5], a Horizon 2020 EU-Japan project which aims at creating a "virtual coach" to support healthy living of adults in the age range of 65–75. The framework of e-ViTA roughly contains a front-end device, such as a robot or even a tablet, a network of sensors, a dialogue system, and a middleware. However, not any socially assistive robot can be used for this purpose. User acceptance can be tricky to achieve when dealing with older generations, and this is a factor that may act as bottleneck for whatever coach could be made. The first impact is necessarily related to exterior appearance: this implies that a robot has to be carefully designed, in order to ensure users' acceptance. Numerous previous studies, such as [6–8] have shown that the acceptance of robots is related to the background culture of the user, and even religion can be a critical factor [9]. In addition, older generations are known to often experience difficulties in the use of technological devices [10], such as mobile phones. Recent surveys [11] as well highlighted that the positive view of robots decreases with age.

Under these premises, the design of DarumaTO-3 (refer to Fig. 1) was conceived, inspired by Japanese folklore. DarumaTO is a social robot that can look familiar to Japanese older adults, being inspired by the traditional Buddhist and Shinto doll called Daruma. The robot we are introducing in this paper will act as one of the potential front-ends of the virtual coach. Its development is based on participatory design, which takes consideration of end-user and stakeholder needs and concretely presents them evolutions of the prototypes in an iterative manner. Through a sequence of steps, the development is expected to become optimal. This paper covers the development of the first improved prototype of this Daruma robot compared to the existing version made in 2016 [12], and reports on a session of interactions with older adults. Through qualitative analysis of the responses we attempt to validate needs, barriers and effects, and also to explore new ideas.

2 Social Robot DarumaTO-3

DarumaTO-3 (*Daruma Theomorphic Operator v3*) is the evolution of the 2 DoF DarumaTO-2 [12], from which it retains the mechanics of movement, which

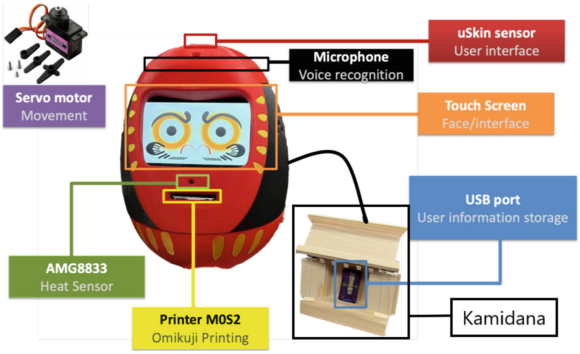

Fig. 1. DarumaTO-3 hardware configuration

therefore will not be described in this paper. This new version is the first one to be tested with an extended number of subjects. Compared to the previous model, it features a re-designed rounded shape. It does not feature a camera, however it has additional components which are listed in the next subsection. DarumaTO is able to communicate with people with simple dialogue as well as the facial expressions. Therefore, its inputs include voice and touch, and as a possible novel way of displaying output information, it can print out a "omikuji" (a fortune-telling strip written on paper at Shinto shrines and Buddhist temples in Japan).

Inside DarumaTO-3, a Jetson Nano is connected with the sensors, including a heat sensor, touch sensor and microphone; a touch screen to interact with the user; two servo motors to control yaw (right-left) and pitch (up-down) movements; a printer to print out omikuji, advice and reminders; and an external cabling to a Kamidana (a miniature household altar that enshrines a Shinto Kami (God), as shown in Fig. 1). The detailed description of each part follows.

- Heat Sensor (AMG8833): It is an infrared array sensor Grid-EYE 8X8 provided by Panasonic. It is connected with Jetson Nano to deliver values from thermal detection to give feedbacks for Daruma to do reactions and interactions with the user.
- Motor (MG996R): The motor is a high-torque digital servo featuring metal gearing resulting in extra high 10 kg stalling torque in a tiny package. Two motors are used to create yaw and pitch movements.
- Microphone (iGOKU): The microphone is used to detect and record the voice of the user, which will be processed by a speech recognition module.
- Printer (Phomemo MO2S): The printer stands inside the mouth of Daruma, is connected with Jetson Nano to print out omikuji automatically every day when the user connects with it. As different types of conversations get developed, it is expected to print out also advices, notes and reminders. This one of the first robots that incorporates a mini-printer. To our best knowledge, the only other case is BlessU-2 [13].

- Touch screen (EVICIV 7): The touchscreen is about 7 in. with 1080P resolution. It is used to express the facial expressions of Daruma including blinking, winking, smile, angry face, and others.
- uSkin sensor (XELA Robotics) [14]: Currently, it is used as a switch to activate Daruma. It can be also used as a touch sensor to monitor tactile interactions.
- USB: the USB memory that contains the personal information of the user is covered by a sachet symbolising a "Omamori" (a Japanese amulet commonly sold at Shinto shrines and Buddhist temples, dedicated to particular Shinto gods as well as Buddhist figures, said to provide various forms of luck or protection). When the USB is plugged in, Daruma will be able to know the user name in advance; otherwise, Daruma will only perform simple conversation without any personalisation.

3 Participants and Methodology

The experiment was conducted as a form of semi-structured interview at Tohoku University, Sendai. The 44 participants were all 65 years old or older (the average age is 71.30, the age standard deviation is 2.91) and live independently at home.

In Table 1, the information about older adults were collected including (1) whether they are living alone, (2) how often they contact with their family, (3) health, (4) lifestyle, (5) religion, (6) how familiar are they with technology, and (7) how often they use a tablet or smartphone.

Table 1. The overview of all the subjects

Sex	Female: 28; Male: 16
Living alone	Yes: 12; No: 32
Contact with family	Never: 1; Rarely: 1; Sometimes: 10; Often: 8; Always: 24
Health	Poor: 1; Fair: 15; Good: 7; very good: 11; Excellent: 10
Lifestyle	Not at all busy: 11; Somewhat busy: 15; Busy: 12; Very busy: 2; Extremely busy: 4
Religion	No: 33; Yes: 11
Technology	Not at all familiar: 15; Somewhat familiar: 18; Moderately familiar: 6; Very familiar: 4; Extremely familiar: 1
Using tablet or smartphone	Never: 4; Rarely: 5; Sometimes: 7; Often: 1, Always: 27

Fig. 2. Interview after interaction session

The experiment was carried out in three steps. First, before Daruma was introduced to the participants, the interviewer explained about the concept of coaching devices. Second, there was a short introduction to Daruma and interaction session. In this session, Daruma communicated with the participants through four use cases: welcome greeting and self-introduction, printing omikuji, reminder and final greeting. These four use cases mimic the typical use cases which will happen in a long-term interaction. Third, the participants were asked to judge Daruma's (1) usability, (2) animacy, (3) likeability and (4) uncanniness, and to (5) freely express any opinions about the device((refer to Fig. 2)). All of these are relevant indicators of the way DarumaTO should be developed. Usability is a common indicator for products, and particularly relevant in the case of older adults. Animacy gives an idea of how the robot is considered. Likeability is a common measurement for robots, and possible uncanny aspects necessarily need to be highlighted if present. During the open interview session, other opinions regarding DarumaTO's shape, colour, motion, and many other features also were collected from the users.

For the measurement of (1) usability, the System Usability Scale (Brooke, 1995 [15]) was adopted, and for (2) animacy and (3) likeability, the Godspeed questionnaire (Bartneck [16]) was used. Due to the age of participants, and the inconvenience of written questionnaires for them, these scales were used as a reference, with the interviewer reading the adjectives, and trying to identify the user's opinion on a scale of 1 to 5. It should be noted that the scores of (1)–(4) were not provided by the participants #10–#17 as Daruma had a malfunctioning that did not allow an informed judgement.

4 Results and Discussion

Based on the participants' judgements on Daruma, the experimental results are illustrated in Fig. 3. The results can be summarised in four features which are usability (did you find it easy to use?), animacy (did you feel it lifelike?),

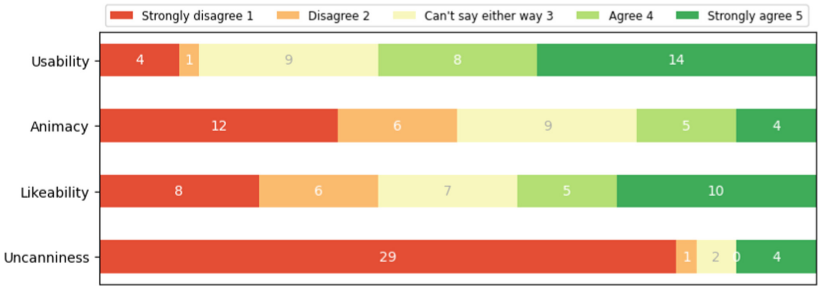

Fig. 3. Results of the guied interviews: positive adjectives are on the right

likeability (did you find it likeable?), and uncanniness (was it uncanny, scary, or uncomfortable?). In Fig. 3, it is possible to see each feature graded in a 5-points Likert scale [strongly disagree, disagree, cannot say either way, agree, and strongly agree].

4.1 Usability

The results of Usability (mean: 3.47; median: 4; standard deviation: 1.77) in Fig. 3 suggests that the majority of the participants agreed that Daruma was easy to use. Regarding the reason, four participants stated that it was good to be able to manipulate it by voice.

Based on the result above, it seems to be better for Daruma to be controlled by voice as much as possible, without adding many parts and buttons. The lack of sense of pressing the button seems to promote anxiety of the users because they do not know whether the robot understands what they say, or whether they can manipulate it in a right way, so these issues must be solved.

4.2 Animacy

According to the results of Animacy (mean: 2.53; median: 3; standard deviation: 1.86) in Fig. 3, the majority of people did not feel Daruma lifelike.

We consider a good achievement already to receive these mixed results to animacy. While its links with acceptability need to be clarified, it is important to note that animacy may be an aspect that is particularly culture-specific.

In order to have a clear idea of the perception of DarumaTO-3, we are introducing the use of the "tool-agent spectrum" (Fig. 4). which was proposed by Rozendaal [17]. Our contribution in this spectrum is that we measure the two axes with the above mentioned scales of usability and animacy. In Fig. 4, "tool" refers to an object that enables users to do what they want, and "agent" refers to an object that behaves as if it has autonomy. The object can be called "partner" when they have the characteristics of both "tool" and "agent". The overall goal in line with e-ViTA project is, in fact, of pushing the evaluation as much as possible close to "partner". According to the mean score of usability and animacy

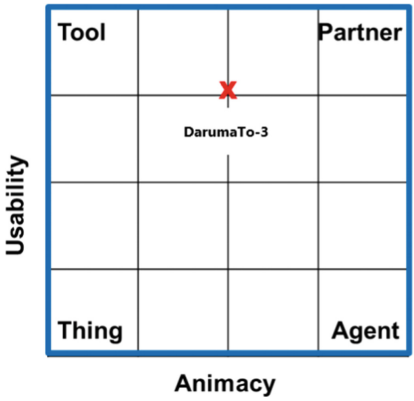

Fig. 4. Tool-agent spectrum with the result of this session

above, which are the vertical and horizontal axis respectively, DarumaTO-3 can be positioned just at the midpoint between "tool" and "partner". The next steps of evolution of this robot will be mirrored on this spectrum and compared to the previous instances.

4.3 Likeability

The results of Likeability (mean: 3.08; median: 3; standard deviation: 2.30) in Fig. 3 shows that the number of people who liked Daruma was almost the same as that of those who disliked it. While this may seem a not so positive result, we believe that the concept itself of a robotic Daruma leads to polarised opinions influenced by the personal background. In addition, being a session aimed to co-design, we left the discussion open about many personalised details such as shape, colour, voice, motion, and other features. More insights are presented in the Subsect. 4.5 Interview session.

4.4 Uncanniness

Based on the results of Uncanniness (mean: 1.58; median: 1; standard deviation: 1.69) in Fig. 3, it is indicated that most of the participants did not think Daruma as uncanny. While this result was very positive, here we highlight the negative comments only. Among those who answered "extremely", the participant #2 stated that "I don't understand why it was designed as Daruma. I think there is a misunderstanding by foreign people that all Japanese people like Daruma" and #42 argued "Daruma should not speak."

4.5 Interview Session

In the interview session, the impression of DarumaTO is collected and summarised as Table 2, where we report the (in our opinion) most critical and

therefore useful comments. Desirable features were also collected and they are summarised in Table 3. Popular suggestions were coaching on cooking and health, measuring blood pressure, fortune telling, simple games, interesting stories, personal conversation, weather, news, searching information and reminders of the schedule.

When dealing with these results, it is important to note that not all the suggestions necessarily point at the right direction of development. Users opinion are variegated, and those who are a-priori not interested in the device are likely to give suggestions that are misleading for our goals (such as to employ Daruma to look after a dog).

Table 2. Impression from interview.

Impression	Details
Shape and colour	There were a certain number of people who said that it was strange to design a robot as Daruma. Thus, it might be the best to design it just as a round shape with a face. As for the colour, opinions were sharply divided
Size	14 people mentioned that it was too big. The participant #7 stated "It is too big compared to the general size of rooms in Japan (approximately 9.5 square meters)" and #26 said "I don't know where to put in in my house because it is too big"
Voice and the way of speaking	It would be better that the pitch, volume and speed of speaking can be adjusted according to the users' preference. Considering the fact that older adults use dialects more often than younger people, it is desirable if the robot can understand it
Motion	The majority of the participants agreed that the robot had to stay at one place, have a motion of nodding, changing directions and akin to the traditional Japanese doll known as "okiagari-koboshi"
Omikuji	Five people made positive comments while three were negative towards this feature. Five people stated that the letters were too small. There was also a person who claimed "It is hard to cut the paper (#10)" and "The printer was too slow (#28)"

4.6 Other Useful Comments

There were three participants expressing opinions that they did not need such devices as they could do almost everything with their PCs or smartphones. The participant #27 stated "PCs began to be spread when those whose age is in the seventies now started working, so there is a big gap between those who are good at using devices and those who are not in the generation." The participant #20 critically argued "If this device is put into practical use in about 10 years, people whose age is in the sixties now become seventies, and then the majority of these people can take advantage of such a device".

Table 3. Desirable features from interview

Features	Details
Coaching	People requested features concerning coaching. Among them, the most popular was the suggestion about cooking mentioned by 6 people. Health was also considered important
Entertainment	People mentioned features on entertainment. Their suggestion varied from "games (#34)", "rock-paper-scissors (#35)", "future prediction (#25)", "movies and music (#26)", "mahjong (#38)", "gamble such as horse races (#21)" to "what day it is today (e.g., a celebrity's birthday) and today's flower (#20)"
Conversation	Nine people showed interest in having more personal conversation with the robot. Two emphasised that they wanted to be told "Itterasshai (See you again)" when they leave and "Okaeri (Welcome back)" when they get back home"
Reminder	People stated that they wanted it to remind them of the schedule such as when to take medicine or when to go to hospital
Printing	Popular choices were data concerning health, lists for shopping, weather and recipes. While other robots usually provide information only via voice or screen, having it printed seems useful to memorise it
Others	The participant #3 wanted it "to operate inter-connectedly with my smartphone", #33 "to care about my dog", and #29 wanted "to name Daruma by myself." #21 added "If there are too many features, it will become too complex, so it does not have to be too much"

5 Conclusion and Future Works

Ageing society is a global issue for which socially assistive robots need to be specifically designed. We presented the prototype of a new social robot, called DarumaTO-3, made for Japanese older adults, and we performed an experimental session with 44 participants. The overall reaction was quite favourable, as it is apparent that they are willingly to use it if it is easy to operate. From the qualitative analysis of the interviews, a significant insight was that most participants conceive DarumaTO as a stationary object, which makes it feel less threatening compared to moving robots. However, in order to make it a suitable companion, several improvements are needed, especially in the hardware. Interesting data was also collected about the printing feature, which is also relatively novel in thee field of robotics. It appeared that particular emphasis should be placed on any kind of content that may be prone to forgetting, and let the user carry around the information. One additional lesson learnt is about synthesising a considerable amount of opinions, often in contradiction with each other, into useful research directions. This process goes through the understanding that not all opinions matter the same: the participants whose profile matches the traits of a possible "early adopter" weight more. After this experimental session, a re-design phase is going to follow. All the suggestions and critical issues will be considered for the future version of DarumaTO, which will be employed in a long-term study at users' homes.

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