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Deployment of a Socially Assistive Robot for Assessment of COVID-19 Symptoms and Exposure at an Elder Care Setting

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***Abstract*— This work investigates the deployment of an affordable socially assistive robot (SAR) at an older adult day care setting for the screening of COVID-19 symptoms and exposure. Despite the focus on older adults, other stakeholders (clinicians and caregivers) were included in the study due to the need for daily COVID-19 screening. The investigation considered which aspects of human-robot-interaction (HRI) are relevant when designing social agents for patient screening. The implementation was based upon the current screening procedure adopted by the deployment facility, and translated into robot dialogues and gesturing motion. Post-interaction surveys with participants informed their preferences for the type of interaction and system usability. Observer surveys evaluated users' reaction, verbal and physical engagement. Results indicated general acceptance of the social agent and possible improvements to the current version of the robot to encourage a broader adoption by the stakeholders.**

I. INTRODUCTION

The current COVID-19 pandemic has greatly impacted older adults living in group settings, since the risk for severe illness from COVID-19 increases with age [2]. Given the high contagiousness ratio of the disease, especially via community spread [3], extreme caution and use of personal protective equipment (PPE) is needed when assisting older adults with their Activities of Daily Living (ADLs) or Instrumental Activities of Daily Living (IADL) [4], as these activities require human contact.

One COVID-19 related activity at long term care facilities that involves multiple human contact is at the entrance to the facility where all entering clinicians, caregivers, older adults and visitors are screened. Endowing socially assistive robots (SAR)s with health screening capabilities can perform this task with potential benefits beyond reducing human contact. Robots may be more engaging at a personal level, rather than at a general, impersonal. Combining subjective and behavioural measures deemed essential to inform the stakeholder acceptance and usability of the system as well as the improvement of its functionalities, we hope to compare a robot in health screening interaction to a human performing the same functions.

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Fig. 1: COVID-19 symptoms and exposure screening of an older adult by Quori.

We deployed an affordable SAR robot (Quori) at a Program of All-Inclusive Care (PACE) Center for older adults (Fig. 1). The robot screened PACE participants and employees (clinicians and caregivers) for symptoms and exposure of COVID-19 through dialogues and gestures. Every stakeholder (clinician, caregiver and older adult) who consented participated in the study. Data collection included observer and post-interaction surveys with every participant. Results inform aspects of human-robot-interaction (HRI) to consider when deploying robots amidst the COVID-19 pandemic. This screening method can also be useful beyond COVID-19 for example during the annual flu season.

This paper is divided as follows. A brief literature review is presented in Section II. An introduction to our SAR hardware platform and its modifications is described in Section III-A, and deployment methods, experimental results and discussion presented on Section IV. Section V presents conclusion and future work.

II. LITERATURE REVIEW

Recently, numerous works discussing the direct impact of the COVID-19 pandemic in robotics research and development have been presented [25], [26], [27], [28], [29]. A thorough review discussing these impacts on robotic applications, along with possible solutions is found in [32]. As shown in Fig. 2, robotic applications ranging from sanitization (UVD Robots), item delivery in hospitals (Zali Robot), equipment monitoring (Tommy Robot) and health check-ups (Misty II Robot [1]) have been increasingly developed worldwide.

[1] https://www.mistyrobotics.com/

Similarly, robotic assisted surgery (RAS) adoption has shown direct and indirect benefits towards the pandemic. Directly, as less staff (especially surgical teams at the bedside) may be needed to perform various surgeries and consequently reducing the risk of cross contamination between staff and patients. Indirectly, robots may reduce the hospital stay in some procedures, making more rooms available for COVID-19 patients [25]. Expensive robots, however, are difficult to budget for, limiting adoption. Affordable robot solutions are preferred [30]. Stringent cleaning requirements may also impose additional challenges to the hospital staff and therefore logistical planning can become an issue.

Human subjects studies in HRI were negatively affected by the pandemic, greatly limiting HRI research. An overall analysis, both in terms of research praxis, as well as topics is discussed in [31]. Efforts to investigate the potential uses of robots for COVID-19 testing have been recently adopted, since robots can facilitate and increase testing capabilities while minimizing risks of transmission. Testing robots may be patient facing (directly collecting biological material from subjects) or non-patient facing (associated with laboratory testing procedures and teleoperation) [26]. The former has the potential of decreasing the exposure of testing staff and the latter minimizes exposure of laboratory technicians. Despite these benefits, only a few robot arms and teleoperated robots have been tested[26]. Other approaches in COVID-19 robotics response include temperature screening [42], [43] and a cough detection algorithm [33].

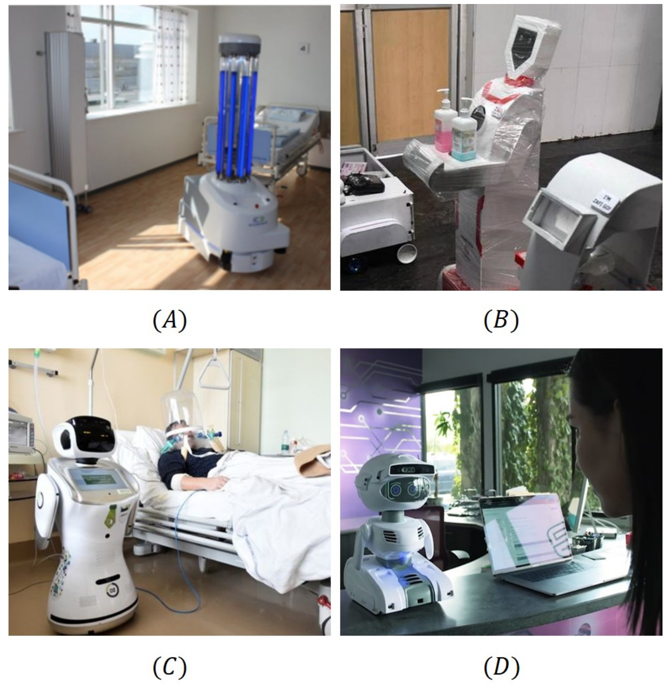

Fig. 2: (A) UVD robots help in infection prevention (UVD Robots Denmark) (B) "Zafi" Robot deployed in Chennai to aid in items transportation (C) "Tommy" robot in Italy aids hospital staff by monitoring parameters from equipments in the room (D) "Misty II" robot performs health check monitoring with options for temperature check and equipment sanitization.

III. Deployment Methods

The current COVID-19 screening procedure at the PACE Center is illustrated in Fig. 3. A total of 3 people interact with the older adults from arrival to being granted access to the day center or sent home, depending on the assessment of their symptoms, body temperature and blood oxygen level measurements (each repeated at maximum twice). The new proposed procedure performed by the robot (Fig. 4) summarizes the main screening routines (Symptom and Exposure), in addition to the temperature screening (not functionally done by the robot). A dialogue between the participant and the robot was coordinated by a finite state machine (described in Sec. III-C). Voice recognition to switch between states (based on the participant's responses) was not utilized. Possible complications with muffling voices by mask usage or difficulty in having the robot near the participant due to COVID-19 preventive measures were the main contributing factors. Therefore, researcher's input (through a joystick) based on the observed response from the participants were the finite state machine guard conditions. A detailed description of the entire system's implementation follows.

A. Hardware and System Review

Previously, the thematic analysis completed for this study [40] indicated all stakeholders expectancy for the robot to be polite and personable. In addition, the importance of design and programming to meet the individual needs of an older adult (either due to their physical or cognitive challenges) was found to be preferred over how the robot should look. All participants were concerned about the safety of the robot. This is consistent with previous study findings [1], [17], [7], in which any device perceived by older adults, caregivers, or clinicians as unsafe would decrease the use of the technology. This original analysis informed the current SAR platform (Quori) hardware and software design.

1) Quori SAR: Quori [24], [41] consists of a humanoid upper body attached to a omnidirectional mobile base. The original modular Hardware (shown in Fig. 5 left) is described as a:

- Holonomic Mobile Base: Inspired by the design in [34] and mobility in [35], the base has three actuators for generating linear and angular velocities as well as orient the upper body of the robot, measuring 480 mm in diameter and 203 mm in height.
- Spherical Projection Head: To maximize flexibility and minimize cost, Quori's head consists of a retro-projected animated face (RAF) using a portable projector, a lens (or mirror), and a projection surface. This leads to versatility since any face can be projected, and highly expressive, and give the illusion of rotation or nodding without requiring motors to move the head [36], [37], [38].
- Gesturing Arms: The arms are used for gesturing not for manipulation. Two DOF shoulders are designed so

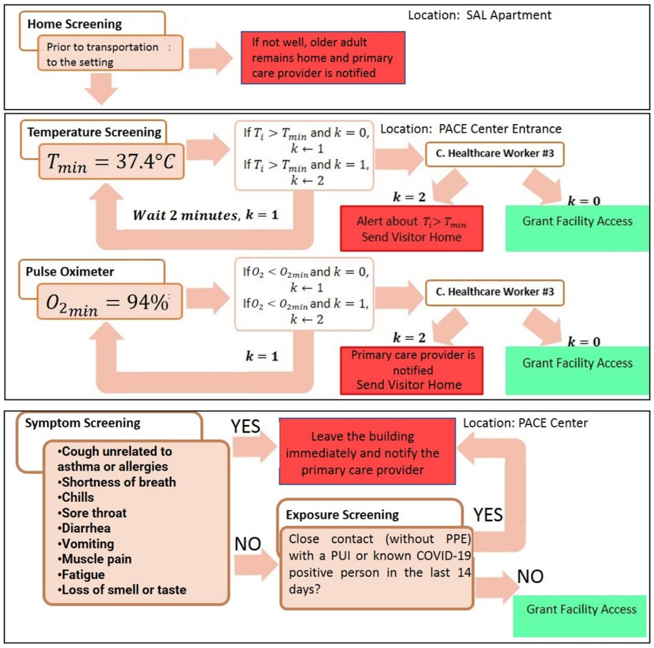

Fig. 3: Screening Procedure at the PACE Center.

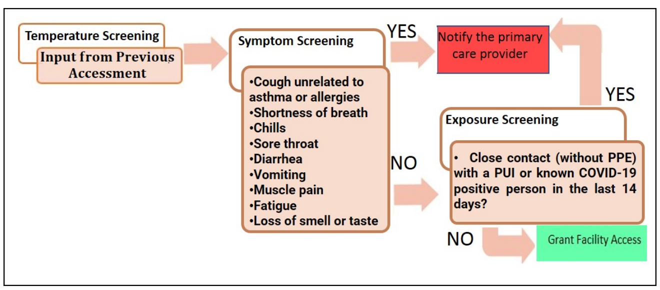

Fig. 4: Screening Procedure performed by the robot.

that the arm can rotate continuously. Safety concerning proximity to humans was also considered by limiting the torque on the drive motors as well as using lightweight materials and low inertial, and stiffness arm.

- Spine In order to support the torso, a 1-DOF spine allows the robot to demonstrate different levels of engagement by leaning forward or backward. The spine can also minimize possible vibrations due to the robot's motion, resulting in natural and more appealing motion.

2) Hardware Modifications: Since the check-in procedures mostly required dialogue and indication of directions (for medical appointments for instance), the robot remained in one location and the holonomic base was simplified to a purely rotational one. Another modification to the original hardware was the addition of the Radio Frequency Identification (RFID) reader to the robot. Relying on RFID for person identification is preferred as the subjects were wearing face masks, which imposed challenges to the implementation of facial recognition. The reader uses USB communication, has a 1m range and emulates a keyboard. To facilitate comprehension for hearing impaired older adults and promote physical distancing, external speakers were located near the

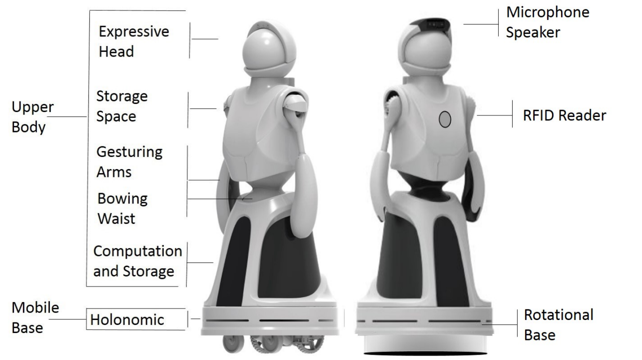

Fig. 5: Quori (left) and hardware modifications for deployment in the proposed study (right)

participants. Lastly, since body temperature can vary depending on the location of the measurement, and older adults and employees would only be admitted to the facility with body temperature under 37.4^{o}C, no temperature screening device was added to Quori. Temperature screening dialogue, however, was included in the dialogue simply to provide more context and completion to the overall interaction.

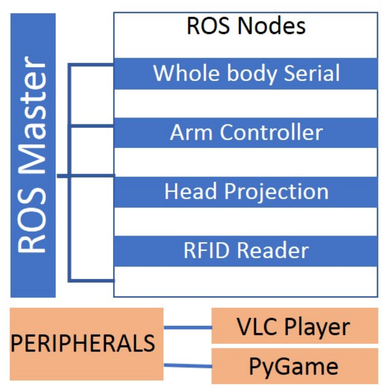

Fig. 6: The software implementation framework. The ROS Master node controls the robot motion and facial expression. The peripherals manage the finite state machine abstraction for dialogue.

B. Software Implementation

An overview of the software framework is seen on Fig. 6. The robot architecture uses Robot Operation System (ROS)[2] for its main implementation. The core body motion of the robot runs on a *Whole body Serial* node, and the gesturing arms driven by anti-cogged brushless DC motors[3] running a PID controller (which considers torque and speed limits for the motion as safety precaution during interaction), implemented on an *Arm Controller* node. We have utilized a simple facial expression consisting on periodic blinking eyes with the intent to generate empathy and not overstate the

[2]www.ros.org
[3]http://iq-control.com/

TABLE I: Participants Demographics

Gender	Male 11	Female 28	Total 39
Age	25-50 10	51-60 12	61 or older 17
Race	African American 36	Other 3	Total 39
Status	Employee 22	Member 17	Total 39

robot's intelligence, implemented on the *Head Projection* node. Dialogues were input to a text-to-speech engine [4] and *mp*3 files were generated and played by the *VLC Player* peripheral. A low pitch and speed voice was preferred since those can impact the ability of the older adult to hear the interaction [46]. Finally, switching between states was done with a joystick using *PyGame* implementation.

C. State Machine Implementation

The interaction was implemented as a finite state machine (Fig. 7). To begin, the *RFID Reader* node utilized the USB reader device and RFID tags (*STATE* 0). The robot greeted the participant by name and prompted them to remain steady while it (in a "Wizard of Oz" manner) checked their temperature (*STATE* 1). After a 5 second delay, the robot engaged in a symptom check routine (*STATE* 2), inquiring users' input on a list of symptoms (shown on Fig. 4). If the participant answered *YES* to any symptoms on the list, the robot referred (vocally and pointing) the user to a physician's room (*STATE* 3) and the interaction ended. Otherwise, the robot engaged in an exposure check dialogue (*STATE* 4), asking if the participant has had any close contact with a COVID-19 positive person in the last 14 days without a mask. Once again, a positive response referred the user to a physician (*STATE* 3), otherwise to a caregiver (*STATE* 5), finishing the interaction in sequence.

TABLE II: Access to Technology

Experience with or use a
Computer 28
Tablet or e-reader 20
Cellphone 38
Exercise daily* 24

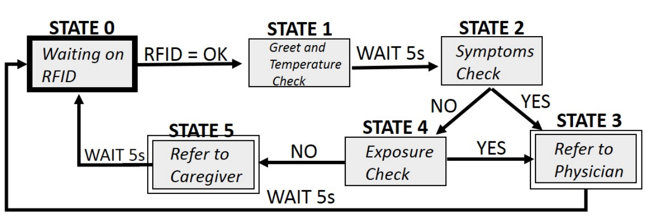

Fig. 7: Finite State Machine for dialogue and interaction. Details of the dialog are in Fig. 4

[4] www.kukarella.com

IV. Deployment Results

Figure 9 shows the experimental setup. The robot was placed at the dining hall of the PACE Center and participants instructed to interact with it (standing or seated, depending on their mobility limitations) at a $1m$ distance. Third (Fig. 1) and first-person (Fig. 8) view cameras were used to record every interaction, capturing participant's body language and face reactions.

Fig. 8: First-Person view camera installed on the robot.

A total of 39 participants interacted with the robot (see Table I for demographics). Almost all participants were African-Americans, 61 years and older and had cellphones (Table II), with the majority having access to a computer and roughly half to tablets or e-readers on a daily basis. The research team conducted post-interaction and observer surveys to analyze responses subjective and behaviorally. The subjective investigation considered two surveys: one based on the Almere [6] model for assessing technology acceptance for older adults, focusing on system usability (Fig. 12); a second (discussed in Sec. IV-A) with open-ended questions about positive and negative aspects of the robot, preference among human, robot or phone screening, and recommendation of use. The behavioral evaluation by an observer also considered a survey (Fig. 10), which indicated additional reactions of the participants while interacting with the robot. The evaluation criteria included: ability to see and hear the robot, facial expression of the participant (smiled, frown) during interaction, physical response, difficulty (or lack of) in understanding and following instructions and possible frustration. Robot errors were also monitored (Fig. 11). Initially, given the equivalent ratio of members (17) to employees (22), groups had their responses separately analyzed, and expressive differences in results (if any) reported as follows. Care was also taken to avoid the observer (or "Hawthorne") effect [45] during the interactions. All participants were consented prior to each interaction. The study was approved by the Institutional Review Board (IRB) of the University of Pennsylvania.

A. Discussion

According to Fig. 10 almost no participant had trouble seeing the robot, was frustrated, upset or bored with it. No participant seemed scared or became unsteady during the interaction. Almost all participants talked back to the

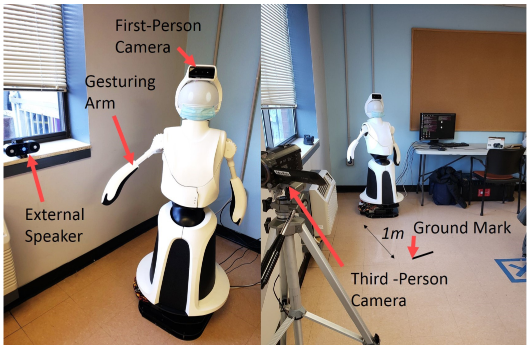

Fig. 9: Experimental setup in the common area. External speaker location depended on participants position standing or seated. The robot to participant distance set at 1m.

robot when questioned by it, smiled (heard as a laugh) and seemed comfortable with it. However, 44% of participants had trouble understanding the robot and 36% trouble hearing it. These were correlated, as participants often complained they could not adequately hear the robot, despite maximum volume of the external speaker. It was observed high background noise from the room's television and employees conversation. A surprising 77% of participants seemed uncomfortable during the interaction. Although not pain related (as only one participant reported pain), a few factors could have contributed for this observation, specifically:

- The repetitiveness of a daily screening procedure (especially for the older adults, since most were screened twice before arriving to the center)
- The inability to hear the robot and not knowing what to answer at times, robot errors due to mispronunciation of names and words (Fig. 11).
- Possible embarrassment in answering to certain screening questions (e.g., "vomiting" and "diarrhea").

With respect to the system's usability (Fig. 12), the majority of participants strongly agree they would use the robot frequently, were confident using it, felt it was easy to use and its functions were well integrated. Participants also think little to no prior knowledge or assistance would be needed before using the robot, and found the system consistent and of low-complexity in general.

B. General Observations

Participants were asked whether they would recommend the robot to a friend (Fig. 13 top). All employees answered positively and 94% of older adults would recommend the robot. When asked about their preference among different COVID-19 screening methods, employees preferred the robot over any other method, although almost 30% did not have a strong opinion. For older adults, more than half preferred human assessment over the robot, the latter in fact was rated the least screening method preferred (11.8%). This is an interesting finding, since despite most older adults recommended the robot, they would still prefer the human assessment. This preference was reflected in statements such as "a person can handle the information", "computers make

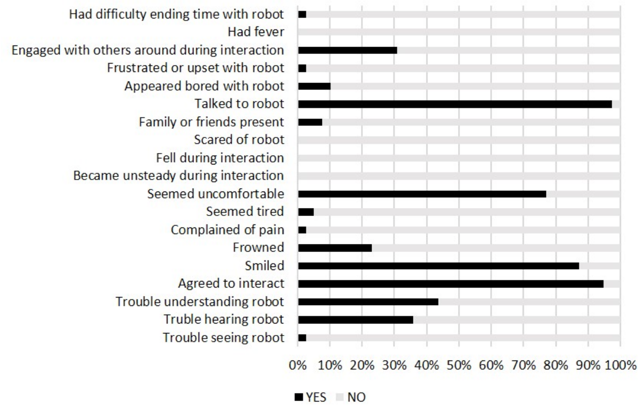

Fig. 10: Observer survey results assessed by the research team during interactions.

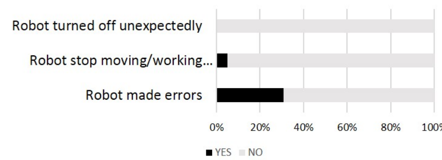

Fig. 11: Observer survey results regarding the robot's observations.

mistakes", "you can ask a person a question", "I can relate to a person" or "I am old-fashioned". Statements for robot screening were "it avoids physical contact", "responses can be kept confidential" and "it is easy to interact". We also asked subjects positive and negative aspects about the robot (Fig. 14). The most positive aspects included being straight to the point, friendly, calling participants by their names and having a clear voice. Most participants did not have negative comments, except for difficulty hearing the robot.

C. Anecdotal Conclusions and Observations

- Getting older adult participants was difficult. The pandemic drastically limited the number of PACE members allowed inside the day center.
- The robot was not allowed in smaller rooms so was set it up in a common area. This included background

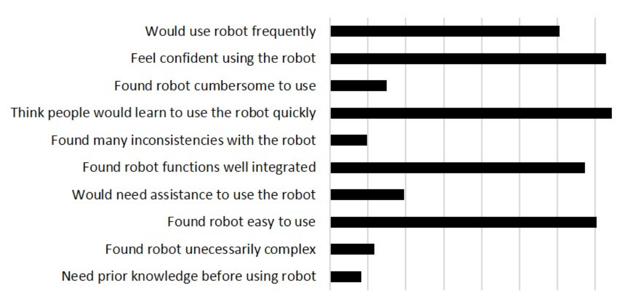

Fig. 12: Agreement Scores for system usability, with 1 (strongly disagree) and 5 (strongly agree) scores.

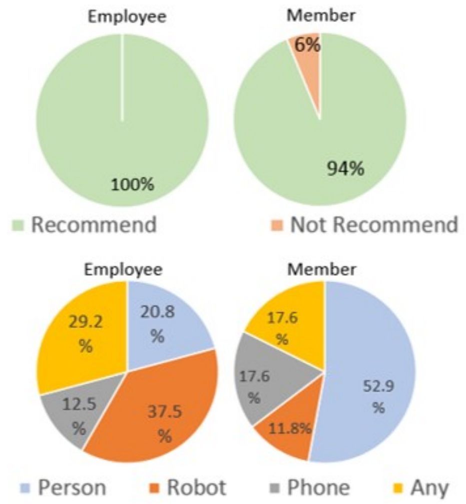

Fig. 13: (Top) Members (older adults) and employee's response on recommending the robot and (bottom) preference towards different types of COVID-19 screening procedures.

noise (such as television and conversations) challenging comprehension for hearing impaired older adults.

- Placement of an external speaker had an impact on the interaction. When the device was placed to the right of one participant (and to the left of Quori), and the asked "look at me for five seconds while I measure your temperature", the participant turned towards the speaker instead of the robot.
- Quori's slow low pitch voice (to facilitate older adult's understanding) seemed to affect younger participants, as one commented "the robot talks too slow and made me a little impatient".
- Additional comments by participants considered the robot easy to speak with, quick to interact, pleasant, and suggestions included more interactive movements and sense of humor.

V. Conclusion and Future Work

This study investigated interactions of a SAR robot at an elder care PACE center for COVID-19 symptoms and exposure screenings. The system dialogue was implemented as a finite state machine using ROS framework, and state guard conditions manually input by the researcher in lieu of a voice recognition or user input system. Subjective and behavioral measures were extracted from post-interaction surveys with participants and observers. Overall results indicate acceptance of the robot as a screening method, in view of its easiness of use, direct and straight to the point behavior, as well as friendly aspect, although the older adult population still preferred a person assessment instead. Despite additional speakers' use, difficulty hearing the robot (especially among older adults) was still noticeable, emphasizing the challenges in designing social robots deployed at common areas and for different age groups.

Objective measures from the study will be evaluated next. Audio volume responses and video analysis can optimize autonomous systems on dealing with complicating factors such as population age difference and facial mask usage. Future deployments with more diverse groups can inform additional needs and improvements to the system not captured in this study. Finally, empowering the robot with other functionalities such as COVID-19 testing and ambient sanitizing can be explored as future work.

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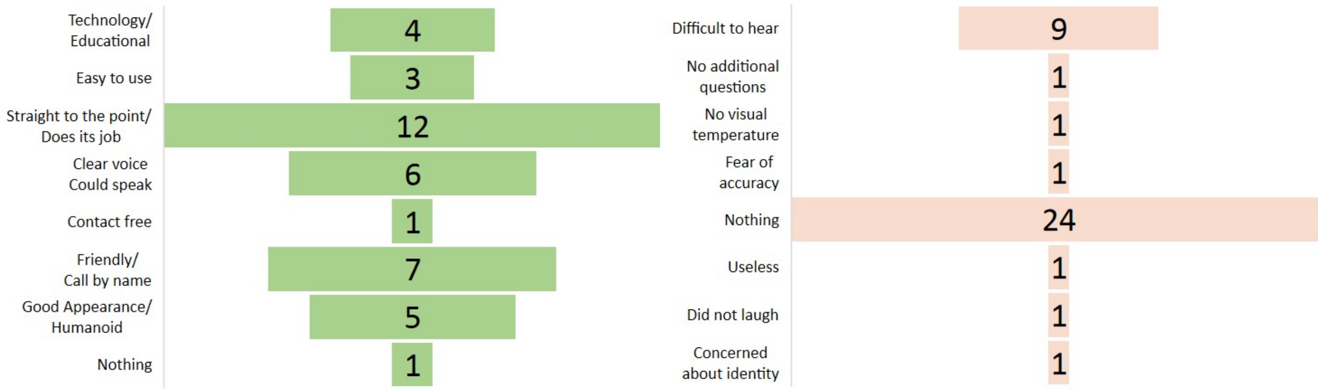

Fig. 14: (Left) Positive and (Right) negative aspects of the robot interaction by the participants.

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