Designing Telepresence Robot Systems for Use by People with Special Needs

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***Abstract*—With the recent emergence of several new telepresence robot platforms, companies are investigating these technologies for ad-hoc conversations beyond the conference room. This technology has the potential to increase cohesion for people who work in a remote location away from their team. We hypothesize that seniors and people with disabilities may find similar benefits while remaining connected with their remote family and friends. We discuss our design of a telepresence robot system for use by this target population. We describe an upcoming pilot study in which people with special needs will operate the telepresence robot at their families' homes and discuss the potential of these robots for telecommuting.**

I. Introduction

For people with special needs (i.e., seniors and people with disabilities), a person's quality of life may be impacted when he/she is no longer able to participate in every day activities with family and friends. Isolation can lead to feelings of overall sadness which can lead to additional health issues [1], thus there is the belief that social engagement can help to mitigate depression. Researchers have investigated robots as social companions such as Paro the baby harp seal [2], Robovie [3], and Pearl the Nursebot [4] (see Broekens et al. [5] for a survey). Beer and Takayama note that there is a difference between companion robots and robots designed to promote social interaction between people as telepresence robots can do [6].

Telepresence robots provide interactive two-way audio and video communication. Additionally, these telepresence robots can be controlled independently by an operator, which means that the person driving can explore and look around as he/she desires. We have conducted previous research to determine what types of office workers might have the most positive experiences using these telepresence robots in an office environment [7]. We found that people who used to be collocated with their teammates and then became remote workers had the best experiences recreating the closeness with their teams using telepresence robots. We hypothesize that similar benefits can be gained by people with special needs who wish to engage in social interaction but cannot be physically present with their families and friends.

Assistive technology benefits directly from the consumer electronics market. Thus, given the recent emergence of a number of telepresence robot platforms (i.e., Giraff Technology's Giraff [8], RoboDynamics' TiLR [9], Anybots' QB [10], VGo Communications' VGo [11], Willow Garage's Texai [12], Gostai's Jazz [13]), we believe that people with special needs will adopt this new technology.

Our research focuses on the scenario in which people with special needs take the active role of operating telepresence robots. In the first stage of our research, we are investigating what autonomous robot navigation behaviors are necessary, how these navigation behaviors should be designed to function in social situations, and how a user interface to control a telepresence robot should be designed for people with special needs with a simple and minimal aesthetic. In this paper, we discuss our overall system design and the experimental design of a pilot study which will run from the middle of May 2011 through the end of July 2011.

II. Related Work

There are two scenarios in which telepresence robots can be used with people with special needs. In the first scenario shown in Fig. 1 (left), a telepresence robot can be located in the residence of the senior or person with a disability; healthcare attendants and family members can then call in and operate the telepresence robot to check on the person. This scenario has been actively researched. The InTouch Health Remote Presence (RP) robots have been used in hospitals by doctors to conduct their patient rounds [14], and by healthcare staff at rehabilitation centers [15] and community eldercare facilities [16]. Telepresence robots, such as Giraff [17], Telerobot [18], TeCaRob [19], TRIC (Telepresence Robot for Interpersonal Communication) [20], and Care-O-bot [21], were designed for home care assistance so that healthcare

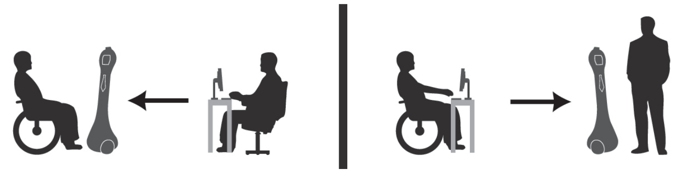

Fig. 1. (Left) A family member visits a person with special needs, who is passively interacting with the telepresence robot. (Right) A person with special needs is actively operating the telepresence robot to visit with a friend.

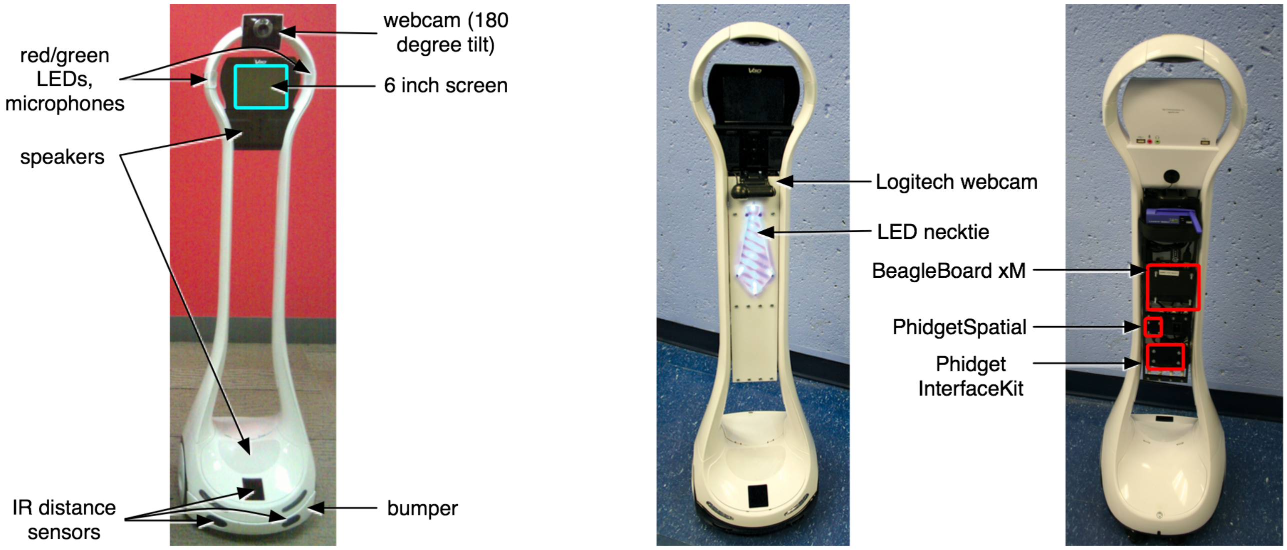

Fig. 2. (Left) A VGo Communications' robot used from June through August 2010. (Right) Front and back views of our augmented VGo robot, Hugo.

professionals, caregivers, and family members could check seniors and people with disabilities when necessary.

Beer and Takayama conducted a user needs assessment of seniors (n=12; ages 63-88) with a Texai robot [6]. The participants were visited by a person who operated the Texai (as in the first scenario). The participants also assumed the role of operator and controlled the Texai to interact with a person, which is an example of the second scenario shown in Fig. 1 (right). The researchers found that in post-experiment interviews, the participants discussed significantly more concerns when visited by a person through the telepresence robot (as in the first scenario) than the condition when they operated the Texai telepresence robot (as in this second scenario), which implies that seniors are willing to operate telepresence robot systems. With respect to where the participants wanted to use the telepresence robots, Beer and Takayama reported that 6 of 12 participants wanted to use the robot outside, 5 wanted to attend a concert or sporting event through the robot, and 4 wanted to use the robot to visit a museum or a theatre.

There are few examples, however, of people with special needs using telepresence robots in the real world. PEBBLES^{TM} (Providing Education By Bringing Learning Environments to Students) was developed by Telebotics, the University of Toronto, and Ryerson University as a means for hospitalized children to continue attending their regular schools [22], [23]. PEBBLES has been used across the US since 2001 including at UCSF Children's Hospital, Yale-New Haven's Children's Hospital, and Cleveland's Rainbow Babies and Children's Hospital. A PEBBLES robot is placed at the child's school, and the child uses a computer station or another PEBBLES robot to look around the classroom and "raise its hand" to participate and ask questions [24]. However, the PEBBLES robot is a passive mobile system and the robot operator is unable to change the robot's location independently.

More recently in the media has been Lyndon Baty's use of the VGo Communications' VGo robot [11] to attend his classes. Lyndon is a high school freshman in Knox City, TX, who has polycystic kidney disease [25]. He received a kidney transplant at age 7, but when Lyndon was 14, his body began to reject [26]. Lyndon stayed at home as per recommendation of his doctors so that he would not become sick. After a year of being at home, he now attends school using his "Batybot" and, unlike PEBBLES, can drive from classroom to classroom. Lyndon's mother Sheri said that "the VGo has integrated Lyndon back into the classroom where he is able to participate in classroom discussions and activities as if he were physically there. More importantly, the VGo has given back his daily socialization that illness has taken away" [26].

III. System Design

A. Robot

We selected the VGo Communications' VGo robot [11] as our base platform (Fig. 2 left). The VGo robot retails for $6,000 USD. It uses two wheels and two rear casters to drive; its maximum speed is 3.0 mph. The VGo robot is four feet tall (48 inches) and weighs approximately 18 lbs with a 6-hour lead acid battery; a 12-hour battery is available. It has a six inch display with two pairs of front and rear microphones and red and green status LEDs on either side of the display. On top of the display, there is a forward facing camera on a servo motor that can tilt up and down 180 degrees. There are two speakers on the robot with the woofer in the base of the robot and the tweeter in the "head." The robot driver uses the VGo Communications' video application on Windows 7/Vista/XP to drive the robot using arrow keys to move the robot forward, back, left, or right. The robot driver can also use a mouse to indicate a "Click and Go" velocity based on the the angle and magnitude of the distance from the center point at the bottom of the video window.

We have augmented the VGo robot with additional processing and sensors (Fig. 2 right) based on guidelines that we developed for telepresence robots (see [27] and [28]). A

Beagleboard xM-B with an ARM® Cortex^{TM} -A8 1GHz processor and 512 MB RAM runs Ubuntu 10.10. The BeagleBoard receives and logs latched TCP robot movement commands; these commands are then sent to the VGo base using serial communication. An IguanaWorks IR transceiver sends camera commands to the VGo head using the Linux Infrared Remote Control (LIRC) package. The BeagleBoard also sends a UDP gStreamer video stream from a Logitech WebCam Pro 9000, which provides a downward facing view of the base of the robot.

The BeagleBoard interfaces with two Phidget sensors boards and logs the sensor values. The first is a PhidgetSpatial 3/3/3 board which has a three axis compass, a three axis gyroscope, and a three axis accelerometer. The second is a PhidgetInterfaceKit 8/8/8 board which has eight digital input ports, eight digital output ports, and eight analog input ports. The PhidgetInterfaceKit signals a MiniBox DCDC-USB power converter to turn on when the robot leaves its charging station; the converter powers draws 5V directly from the robot's battery and connects the USB peripherals to the BeagleBoard through a 4 port hub. The PhidgetInterfaceKit also illuminates four blue LEDs in a clear Plexiglas necktie on the front of the robot to let the user and interactants know when the BeagleBoard is powered on.

Additional sensors will be added to Hugo in the second phase of this research to implement the autonomous robot behaviors described in the following section. We are considering a Hokuyo URG-04LX-UG01 laser which will be used for moving safely in a person's home and localizing itself in a known environment. Other options for localization may be to use an additional webcam for identifying QR codes or ARTags placed throughout a person's home identifying a specific room or "ground truth" locations; a similar approach could be to use RFID tags read with a PhidgetRFID board. The Hukuyo laser in conjunction with an array of IR PhidgetTemperatureSensors can also be used to identify people near the telepresence robot.

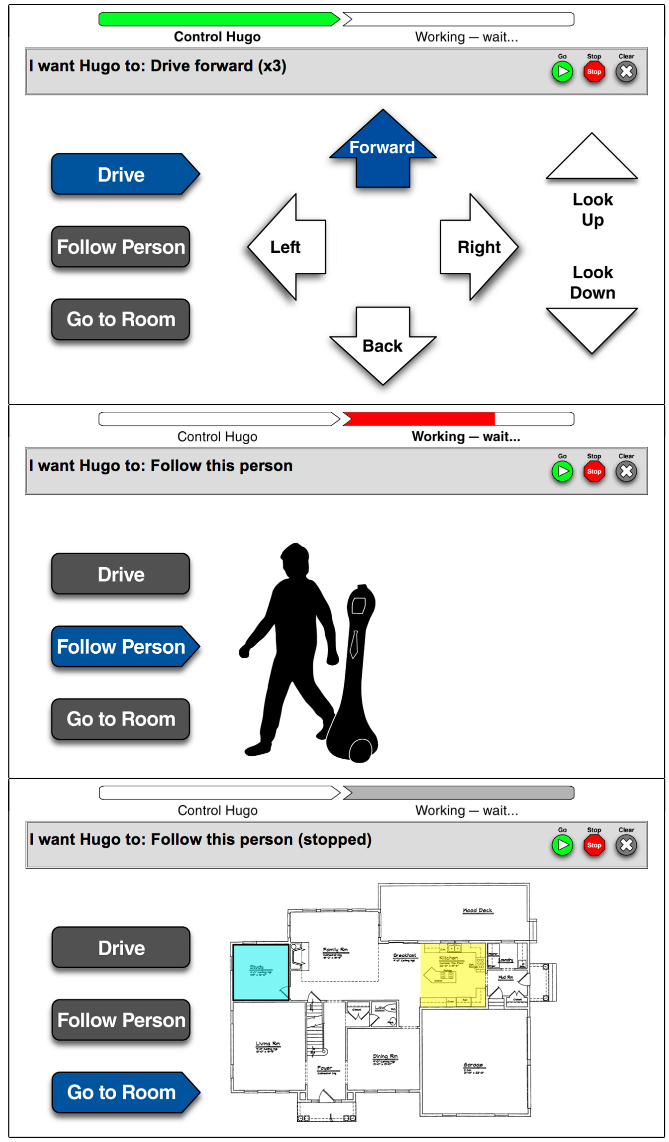

Fig. 3. Our alternative robot control user interface: teleoperated drive (top), follow this person (middle), and go to selected room (bottom).

B. Alternative User Interface

We have designed an alternative user interface prototype for operating the VGo telepresence robot. Our alternative interface was designed for Safari (MacOS and Windows) and is programmed using HTML, Javascript, and PHP. The VGo video is displayed in a separate window to the left of our alternative interface.

When the status bar at the top of the screen shows the left segment as green and "Control Hugo" is bolded (Fig. 3 top), the operator can provide input to the robot. The light gray bar below shows the operator's request, which is an <h1> HTML heading tag (24 point boldfaced type). To the right of the request are three buttons: go, stop, and clear. The operator presses the "go" button when he/she wants Hugo to execute the current command. If the command is valid, a "ding" sounds and the status bar shows the right segment as a red scrolling marquee (Fig. 3 middle). While the command is being executed, the operator can pause the robot's actions by pressing the "stop" button; the right segment of the status bar changes to a light gray color (Fig. 3 bottom). Pressing "go" will resume the robot's action. If the operator wants to cancel the robot's current actions, he/she can press the "clear" button; the displayed request will empty, and the status bar turns back to a ready state with the left segment colored green.

The request is generated from three modes of robot control shown on the left side of the interface as dark gray buttons. When a mode is selected, the button turns dark blue and its text turns white for contrast. The shape of the button changes from a rounded rectangle to a rectangle with right-side arrow edge. The robot control on the right side of the interface changes according to the mode, which we describe below.

Teleoperation. As with the original VGo interface, a person can teleoperate the robot to move forward, backward, left, and right and to tilt the camera up and down. The operator can use a mouse to depress the arrows, use the arrow keys on the keyboard, or a custom jelly bean switch array which emulates arrow key presses. When an arrow is pressed by any one of these three methods, the user interface shows the pressed arrow in a dark blue color and the text of the arrow inverted to white for contrast (Fig. 3 top). When the arrow is released, the arrow returns to the unpressed white image and the drive command is posted to the gray bar.

The original VGo interface provides continuous robot movement which means that the robot would move in the desired direction when the arrow key was pressed and stop when the key was released. However, in a preliminary evaluation, we found that continuous robot movement was an issue with our target population's mental model of the robot due to the latency between issuing the commands, the robot receiving the commands, the robot executing the command, and the video updating to show the robot moving. This issue is consistent with our previous work [7], [27] where we found that able-bodied novice users had difficulty driving telepresence robots straight down a corridor; the latency often caused the robot to turn greater than the desired angle and thus zig zag down the hallway. Therefore, we changed our drive mode to a discrete style which means that one click to left turns the robot a small, fixed turn. To turn the robot a large angle to the left, the operator would click several times. Moving the robot forward and backward are also discrete motions to provide consistency.

High-level autonomous commands. In our previous work [7], [27], we found that 83% of able-bodied novice users (20 of 24 participants) and 79% (19 of 24 participants) thought that it would be useful if the telepresence robots were able to autonomously walk with a person and go to a specified destination, respectively. Thus, we incorporated these two robot navigation behaviors into the alternative user interface. The "follow person" mode will allow the robot operator to autonomously follow the person shown in the robot's video. An icon (Fig. 3 center) shows our robot and a person walking together.

The "go to room" mode will allow the robot operator to specify his/her destination on a map and the robot autonomously navigates there. The floorplan representation was chosen because a map was frequently requested in our prior studies [7], [27]; also, Lyndon learned to navigate his new school using a paper copy of a fire drill map [29]. In our "go to room" mode, each room in a map of the operator's home is highlighted in yellow when a "mouse in" event occurs; Fig. 3 (bottom) shows the kitchen highlighted. When the operator clicks on a room, it is highlighted with a bright cyan rectangle boldly outlined in black; Fig. 3 (bottom) shows the study selected. Then the command is posted to the gray bar. An architectural sample floor plan with room labels is shown in Fig. 3 (bottom). Maps for each operator can be customized with visual support photographs, images, and icons (e.g., pictureSET [30]) thereby further indicating the purpose of each room.

IV. Pilot Study

We will conduct a pilot study in which people with special needs will operate the VGo telepresence robot in their families' homes. These participants are students and clients of the Crotched Mountain Rehabilitation Center (CMRC) community; for clarity, we will refer to these people as "the participants at CMRC." Our goal is to establish if our target population finds benefit from socially engaging with their families through the telepresence robot as compared to a standard video conferencing software (e.g., Skype [31]). The person being visited by the participant at CMRC (herein known as "the remote person") will interact with the telepresence robot for two sessions, and the VGo video conferencing software for two sessions. The starting condition in the initial session will be balanced between the robot and the laptop, and subsequent sessions will alternate.

In the robot condition, the remote person will be visited through our telepresence robot, Hugo. The interface for the participant at CMRC will be the standard VGo Communications video chat window on the left side of the screen and our previously described alternative user interface on the right. He/she will use our alternative user interface to control the robot. The manual drive commands are directly sent to the robot using TCP. For the purposes of this study, the "follow a person" and "go to room" behaviors are accomplished using a "Wizard of Oz" deception [32]. The participant at CMRC will provide his/her desired high level goal, then the "wizard" located with the robot executes the behaviors. The remote person with the robot will be aware that the wizard is operating the robot; the participant at CMRC will be debriefed after all four sessions have been completed.

In the laptop condition, the remote person will use the VGo video conferencing software which is similar to Skype [31]. The laptop provided for this study is the Dell Mini 9 netbook running Windows 7. The screen size is comparable to the VGo's screen and the integrated webcam is in a similar position above the screen. The Windows 7 interface has been replaced with a custom LiteStep interface which allows the remote participant to access the VGo software, view any shared data from the VGo interface, and shutdown the netbook. The interface for the participant at CMRC will be the VGo Communications video chat window only.

The study setup for the participant at CMRC will remain constant for both conditions. An Acer laptop with Windows XP hosts the VGo Communications software. We have mounted a 22 inch Dell monitor on an Ergotron Neo-Flex® Extend LCD Arm which is attached to a 48 inch high pole with a five leg caster base and weighted with a 50 lb weight. External speakers are mounted to the monitor. A Logitech HD Pro Webcam C910 provides the video stream to the robot; the webcam also has two microphones which provide the audio to the robot. An accessibility assessment and training on how to use the robot will occur prior to the study.

A. Data Collection

No video or audio recording will be done during this pilot study. In the robot condition, we will log all of the commands sent to the robot including manual driving, camera movements, mode changes, room selection. We will record the completion of the higher level commands "follow this person" and "go to room." The robot will automatically log the PhidgetSpatial sensor. We will record the length of the interaction. In the laptop condition, we will record only the length of the interaction.

Following the completion of all four sessions (two with the robot and two with the laptop), we will conduct an interview based on the events that occurred during the sessions to gauge if the participant at CMRC found the telepresence robot and the video conferencing software to be useful. We will also interview the remote people. These starter interview questions for the remote person are as follows:

- How often does $<CMRC\_participant\_name>$ come home to see you?
- How does $<CMRC\_participant\_name>$ communicate with you while he/she is at CMRC (e.g., email, phone calls, video conferencing)? How often?
- How do you think you personally would want $<CMRC\_participant\_name>$ to use this robot?
- Would you want $<CMRC\_participant\_name>$ to use a robot like this to talk with you? How often?
- What did you like about the robot?
- What did you not like?
- If you could change anything, what would you change?

The interview questions are similar for the participant at CMRC (reframed for his/her perspective). Additionally, we will ask if he/she would "recommend that your friends use this robot to talk to his/her family?"

B. Recruitment and Participants

Inclusion criteria. Potential participants selected for this study may be students at the school, inpatient clients from the Brain Injury Center, or participants in the residential program. They will be between the ages of 7 to 75 and will have a condition that significantly limits their ability to travel and maintain contact with important individuals in their "regular" environment. Their medical conditions may include disabilities such as Cerebral Palsy, Spina Bifida, Spinal Cord injury, Traumatic Brain injury, or other conditions. People who are non-verbal persons may still benefit, as augmentative communication techniques such as the use of their own speech output device may enable participation in the study. For this pilot study, all participants must be able to share their opinions as to the overall usefulness of this technology.

The remote people must have Internet bandwidth sufficient to operate the VGo robot including in-bound and out-bound audio and video. VGo Communications recommends 768 kbps or better in both directions [33]. Lastly, remote people must be within driving distance of CMRC (located in Greenfield, NH) or UMass Lowell.

Exclusion criteria. People with blindness, severe cognitive challenges, low arousal levels, or other conditions may not benefit from a telepresence robot and thus will not be included in the study. Students or clients with full vision loss will unlikely gain benefit from participating in this exploratory study as the controls for operating the robot are presented on a computer screen and there are no alternative control inputs at this time. Students or clients with severe cognitive challenges will unlikely have the conceptual ability to understand that the telepresence robot is a representation of themselves as opposed to a TV show or video game.

Participants. To date, we have recruited three participants from CMRC:

- P1 is a 34 year old woman who had a stroke while giving birth to her daughter. P1 has limited verbal ability, but has some receptive language skills. She is non-ambulatory and uses a manual wheelchair pushed by an attendant. She has good finger isolation of her right hand and is able to control a television with a remote control. P1 will visit her family at her home.
- P2 is a 57 year old man who has traumatic brain injury. He is ambulatory with a four-legged walking aid. P2 has good verbal ability and receptive language skills and communicates daily with his wife through his cell phone. He will visit with his wife at their home.
- P3 is a 9 year old girl who uses a wheelchair. P3 has good verbal ability and receptive language skills. She has good dexterity in both her hands. P3 will visit with her sister who lives with relatives.

V. Implications for Telecommuting

There is great potential for our research to impact people with special needs both in personal, family scenarios as targeted by our pilot study and also for work-related scenarios. A child's job is to go to school, and in that sense, Lyndon Baty is participating in work via his telepresence robot. Each child with a disability has an individualized education program (IEP) which includes his/her current academic level, annual academic and functional goals, and documentation of special education services and aids [34]. A student's IEP may include assistive technologies such as sensory enhancers, adaptive computer controls, environmental controls, mobility devices, and self-care devices [35]. In [35], robotic devices have been listed under the categories of environmental controls and self-care devices. As telepresence robots prove their value in this use case, we may find telepresence robots explicitly listed in students' IEPs in the near future.

For adults with disabilities, telepresence robots could be used to engage in telecommuting or remote work. According to the Americans with Disabilities Act (ADA), employees and potential employees with disabilities[1] can request reasonable accommodations to the work environment or processes related to their job [37]. Employers are not required to accommodate requests that incur a large expense or are difficult to implement. However, companies have already begun to investigate telepresence robots for ad-hoc conversations beyond the conference room for remote employees to be better connected. As telepresence robots become part of the corporate culture, it will become feasible for more adults with disabilities to telecommute from their residence.

[1]The Americans with Disabilities Act (ADA) Amendment Act of 2008 provided a broader definition of "disability" [36]. These changes have been implemented by the Equal Employment Opportunity Commission (EEOC) and active as of March 25, 2011.

VI. Summary and Future Work

We describe in this paper our first step towards developing a telepresence robot system for people with special needs to operate. The pilot study will begin during the middle of May 2011 and continue through the end of July. We have designed the study to assess if the telepresence robot is perceived as valuable. The current design is largely visual with large buttons and high contrast colors to accommodate low-vision users. As the primary task of the telepresence robot is communication, audio status indicators have been minimally used. Based on the feedback from the study participants, we will iterate on the alternative user interface and input methods. We believe that our system design will be useful for both a home and a corporate environment.

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