Re-purposing Everyday Digital Technology for Marginalised Groups

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Abstract

Smart home technologies, such as Internet of Things devices have great potential to support older people to live for longer in their own homes. Yet individuals with communication, memory and dexterity problems often cannot use such technologies. Through a co-design, participatory approach the needs and problems experienced by older people and their supporters were explored to ascertain how they could be enabled to use Smart home technologies. The solution that was developed, IntraVox, is a virtual hub that enables connectivity from different resources and devices based on the sensor data that is being collected in the house. IntraVox sends various commands to a voice-enabled personal assistant which in return controls smart home devices. This approach can improve the usability of voice-enabled personal assistants by removing the necessity for the user to remember and pronounce specific commands whilst also reinforcing the syntax and the usefulness of those commands. This discussion describes the development process and user-feedback of the IntraVox solution.

Keywords: Technology enabled care, assistive technology, inclusive gerontological care, independent living

Introduction

In the wake of the COVID-19 pandemic, individuals living in different situations, settings, and countries were experiencing the stark reality of connectivity and disconnection with their family and friends, communities, and services. In the UK, there were a myriad of reports of intense isolation that individuals experienced throughout national lockdowns, and the struggles people had in accessing and receiving services in their own homes. Equally, the media reported on the unprecedented national turn to digital platforms as young and old held Zoom parties, Microsoft Teams quizzes, Amazon Alexa concerts to name a few social activities, with new and old devices. Whilst this switch-on to digital living brought renewed interest for many, it also deepened the gap between those able and interested, and those not able to use digital technologies in their own home. This backdrop reframed the direction of a SMART home, independent living project between Northumbria University and Home Group. Home Group, one of the UK's largest providers of quality housing and an offer of integrated health and social care, sought to appraise the needs of its customers to ascertain how customers could be supported by an assistive technology offer that included use and re-purposing of everyday technologies.

Background

Health research studies have been conducted with regards to how smart home technologies can support people in living comfortably and independently. For example, to support healthy aging, low intrusive fall detection systems have been integrated into smart homes. Using WiFi and Bluetooth technologies, systems can detect falls and locate people inside the home. Systems can also send alerts when a fall occurred and can provide light guiding to where the person is located in the home (Pörtner et al., 2015). Muheidat and Lo'Ai (2020) have proposed context-aware and private real-time reporting systems such as smart carpets consisting of sensor pads placed under the carpet. The sensors can detect walking activity, falls, measure gait, and count the number of people walking across the carpet (traversing the carpet would be a good socializing indication). Other systems, focusing on activity recognition, collect data from home appliances, such as TV and fridge to understand the behaviour of older people (Qian et al., 2020). Home environment sensors, gesture tracking sensors, and home appliance sensors have also been used in the development of virtual caregivers for the older population (Rahman and Hossain, 2019). Such systems support householders by reminding them of their to-do list and to take their medication, help them maintain appointments, and control home appliances.

Other smart home technologies, such as Internet of Things (IoT) devices (e.g., robot vacuum cleaners, wireless kitchen appliances, smart sockets, etc.) can support daily activities and improve the quality of life of many user groups. Voice-enabled personal assistants (e.g., Amazon Alexa and Google Home) also have great potential to support people of all abilities and across the life course to live independently at home and to optimize their quality of life (Pradhan et al., 2018). These devices allow users to set reminders, play music, listen to the news, or ask for information such as recipes. Additionally, since they are co-located with householders, they can control various smart home technologies such as light bulbs, thermostats, doorbells and automatic blinds.

Problems older people experience using virtual assistant technologies

Despite being available and affordable, certain sectors of the population do not use smart home technologies. One common issue is that smart home devices are not always fully compatible with the householder's voice-enabled personal assistant. Another issue, particularly relevant for people suffering from various disabilities is the verbal requirement to articulate or recall keywords and specific syntaxes to interact with a voice-enabled personal assistant. For example, to enable the device, one needs to first articulate the wake words (e.g., Alexa/Hey Google), followed by the command: "Alexa/Hey Google, turn on the living room lights". The list of commands constantly expands and grows with every new service or device it supports.

The need to speak clearly and loudly with a voice-enabled personal assistant can be challenging for people with speech impairments and the short amount of time in which the commands need to be spoken can constitute a problem for people with cognitive impairments (Luger and Sellen, 2016, Pradhan et al., 2018). Most users start by interacting with a voice-enabled personal assistant in a natural language but are later forced to limit themselves to just keywords and specific terms to obtain the desired output (Luger and Sellen, 2016). This is because users tend to have a conversational interaction with the device. However, given the one-size-fits-all approach adopted by voice-enabled personal assistants (Sayago et al., 2019), voice user interface devices should not be viewed as conversational agents since they are not able to properly understand the meaning of a conversation (Porcheron et al., 2018).

Approach

A co-design participatory approach was adopted to explore needs and problems experienced by older people and their supporters. Over twelve months, a Community of Practice (CoP) (comprised of end-users/potential customers, carers, social care and health practitioners, managers, and commissioners) took part in a minimum of two workshops. In total, we conducted seven workshops and nine interviews with 79 CoP members. During the workshops, participants considered the challenges they faced which everyday technology might address.

They also engaged in time-line analysis to explore what requirements individuals would have during the day, and ideas for technological solutions that could be achieved through sensing, processing, and actuation. Sensing is when a system can get input from the environment, such as light or sound. Processing is the determination by the system of how to act on that input. Finally, actuation is the process for ‘things’ such as a light being controlled by a computer and causing the action to occur, such as turning on the light. The categorisation of their ideas led to the development of four ‘technology domains’ where technology was considered to have the potential to promote independence and improve quality of life. The domains were:

1. Home Automation – automating the house based on sensors (e.g., sound, light, humidity, temperature, and motion) and use of appliance (e.g., fridge, kettle, microwave) data.
2. Skills Maintenance and Development – supporting individuals to maintain and develop skills such as personal care (e.g., nutritional support, planning to dress appropriately for weather), keeping in touch with others, engaging in interests, and activities (independent studying, shopping), and maintaining environmental hygiene (taking out the bins).
3. Prompts and Reminders – providing alerts to support individuals to complete routine tasks or activities such as making a telephone call, attending an appointment or event.
4. Behaviour and Environment Monitoring – providing supporters, and health and care professionals, access to personal activity and household data.

IntraVox: an enabling solution for use of smart home IoT devices

Smart home IoT devices can transform the lives of older and frail adults and can also help address the four technology domains presented above. As previously mentioned, despite the benefits, commercially available smart home devices are generally not interconnected. Each device is controlled via a separate smartphone application, resulting in users having to install multiple applications on their smartphones. One way to overcome this issue is by using a virtual hub that enables connectivity from different resources and devices. Amazon Alexa and Google Home are the two most used voice-enabled personal assistants that can also act as hubs. Therefore, to address the four technology support domains arising from the workshops, particularly the Home Automation domain, we started by selecting a voice-enabled personal assistant as a hub as this is a readily available technology that is compatible with a variety of smart home appliances.

We also researched motion, touch, proximity, and ambient sensors such as temperature, sound, and light. The challenge, however, was to integrate the different concepts in a system that was easy to use for our potential user group. To address Domain 1 and 4, we started by designing a system composed of motion, touch, proximity, temperature, sound, and light sensors connected to a Raspberry Pi 4B computer, widely used for home automation. Based on the sensor data collected, the Raspberry Pi would send prompts and reminders (Domain 2 and 3) and activate different smart home commands (Domain 1) such as turn on the lights, close the curtains, play music, etc. using a voice-enabled personal assistant.

Development

We initially researched an option whereby the sensors and the Raspberry Pi would control the voice-enabled personal assistant directly without any audible commands. This can be achieved by using various programs that can track, control, and auto-

automate various smart home devices and third-party websites that create virtual Amazon Echo devices. Another possible solution would require putting a set of headphones on the Amazon Alexa to make it a silent process.

We also researched an option where the Raspberry Pi would verbalize the messages and commands using voice synthesis created by text-to-speech libraries. As an example, based on the light sensor data collected, the Raspberry Pi can verbalize a prompt the virtual assistant to trigger certain light processes, such as turning on the lights and closing the curtains as it's getting dark outside. We started by using complex sentences such as "It is getting dark outside. Alexa, turn on the lights." or "Alexa, turn on the lights and close the curtains." However, Alexa encountered difficulties in understanding the commands, regardless of accent and delivery pace. We were, therefore, forced to use basic instructions such as "Alexa, turn on the lights.".

CoP members provided positive feedback with respect to the two options and provided suggestions on how they can be improved. In particular, one CoP member, suffering from a learning disability noted that the silent system might not be appropriate for a person with a cognitive disability as he said that he would find it "scary" and the synthesized voice could be perceived as unpleasant and frustrating. Based on their suggestions we developed IntraVox, a novel voice-based interaction system that introduces a highly personalized, human voice command between IoT devices. The current implementation of the system is composed of a Raspberry Pi 4B computer to which we attached various smart home sensors such as environmental, touch, proximity, and motion sensors (Figure 1). Using a speaker attached to the Raspberry Pi and based on the sensor data that is being collected, IntraVox verbally sends smart home control commands to a voice-enabled personal assistant using a human voice. In our demonstrations, we have used the Amazon Alexa and Google Home voice-enabled personal assistants, but it could easily be generalized to other platforms. As an example, when the environmental sensors detect that the light levels are decreasing as it is getting dark outside, IntraVox will send a command to a voice-enabled personal assistant which in return will control smart home devices, e.g., turn on the lights.

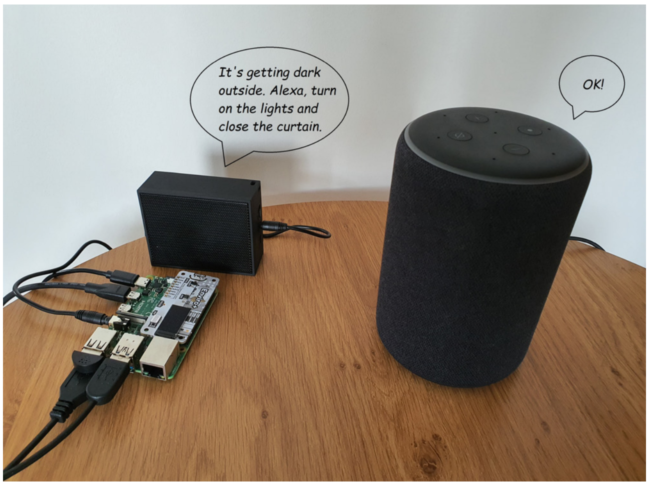

Figure 1: The IntraVox system, composed of a Raspberry Pi 4B computer, sensors, a speaker, and an Amazon Alexa and/or Google Home device controlling smart home appliances. (Ana-Maria Salai)

The development process started by creating the audio files with a human voice verbalizing the preconfigured messages. Using a microphone, these files were recorded directly on the Raspberry Pi. The voice could be a voice recording of a relative, a carer, or any other familiar person. The familiar human voice was used to create a sense of security and comfort as if the person was there to help. Using Python software, whenever a command needed to be sent, the Raspberry Pi would simply play the audio file already saved on its internal memory.

Solutions

As previously mentioned, based on the sensor data that is being collected in the house, IntraVox can send various commands to a voice-enabled personal assistant which in return controls smart home devices. This approach can improve the usability of voice-enabled personal assistants by removing the necessity for the user to remember and pronounce specific commands whilst also reinforcing the syntax and the usefulness of those commands. In addition to the voice-enabled personal assistant commands, we conceptualized the possibility of a stand-alone IntraVox system sending prompts and reminders to users to conduct certain tasks without the use of the voice-enabled personal assistant. For example, using a human voice, IntraVox can verbally send various prompts and reminders such as washing hands after using the toilet, being more active when inactivity is detected, or reminding users to take their keys when opening the front door to leave their home. Use of audio prompting can enhance the independence of older adults and has been widely adopted in technology enabled approaches to assistive living (Pérez-Fuster et al., 2019).

Solution 1 – IntraVox sending voice-enabled personal assistant commands

As previously mentioned, based on the sensor data that is being collected in the house, IntraVox can send various commands to a voice-enabled personal assistant. Since we were using a human voice and we were not facing any memory or time length constraints, we decided to expand the commands and give users a clear cause-and-effect explanation of why certain events occur. This is because, as mentioned by one CoP member, the experience of having smart devices activated without prior notice can be perceived as haunted. We adapted the commands to address scenarios related to the four domains previously mentioned.

Home Automation Scenario - To address Domain 1, based on temperature sensor data, the system can alert users whether it is getting too warm or too cold in a room and will subsequently, turn on or off the heating using the smart thermostat. Based on the light sensor data that is being collected, the system can determine whether it is getting dark outside and trigger a command accordingly: “It is getting dark outside. Alexa/Hey Google, close the bedroom curtains.” (Figure 2). This type of message provides a clear justification for why certain types of home automation processes occur.

Activity Scenario - To address Domains 2-4, we designed an Activity Scenario to engage users with home-based exercises. Based on the user‘s daily

Figure 2: Based on the light level detected by the light sensors, IntraVox will send a command to Alexa to close the bedroom curtains when a decrease in the light intensity is detected. (Ana-Maria Salai)

routine and necessities, if no motion has been detected for a predetermined time, IntraVox would send an instruction to Alexa to start a workout routine: “You haven‘t been active in a while. You should work out, it‘s good for you. Alexa, start 7 minutes workout [Alexa Skill].”. On the other hand, if increased movement is detected, which could be a proxy indicator that the user is agitated, IntraVox would verbalize instructions to Alexa to alleviate the situation (based on the user‘s preferences): “You seem agitated. Alexa/Hey Google, turn living room lights purple and play calming music.”.

Solution 2 – IntraVox sending prompts and reminders

Previous research findings recommend that smart homes should propose rather than impose certain house processes as householders do not like smart homes taking decisions for them (Mennicken et al., 2016). With this in mind and as mentioned above, we designed a second solution where IntraVox would trigger audio messages based on the sensor data collected without having a voice-enabled personal assistant involved in the process. Given this, we designed messages that would empower people to make their own decisions, as follows:

Home Automation Scenario- To address Domain 1, based on the light sensor data collected, IntraVox could prompt the user to take certain actions: “It is getting dark outside. Maybe you should turn on the lights and close the curtains.”. However, this type of message would not be appropriate for people lacking the ability to process the information provided.

Activity Scenario - To address Domains 2-4, if the motion sensors detect inactivity for a certain amount of time, we designed IntraVox to verbalize a reminder such as: “You should be a bit more active, it‘s good for you. How about going for a walk?”.

Hygiene and Dehydration Scenario- To address Domains 2 and 3 and improve the daily living skills of people, using a touch sensor attached to a toilet (Figure 3), IntraVox can send a verbal notification to the users to wash their hands after using the toilet: “Remember to wash your hands after going to the toilet.”. With regards to dehydration, sensors were deployed to determine the amount of water a person is drinking in a day. If the person was drinking less than the recommended amount of 1.5 litres per day (Colley, 2015), a verbal reminder was sent to users to drink sufficient fluid. This was possible by attaching touch sensors to a glass and temperature sensors at the bottom of a mug that could indicate that a drink/hot drink was consumed.

Figure 3: A touch sensor attached to a toilet. Upon using the toilet and touching the sensor, IntraVox will prompt users to wash their hands. (Ana-Maria Salai)

Reminder Scenario: To addresses Domains 2 and 3, using a proximity sensor attached to a front door, users can receive a verbal reminder to take their keys before leaving the house. We expanded the functionality and using various cloud communications platforms (e.g., Twilio, Plivo), IntraVox was programmed to also send an SMS alert to a carer or family member whenever an unexpected or relevant event would occur (e.g., when the front door opened).

CoP member perceptions of the IntraVox solution

The concept of a highly personalized human voice sending prompts and reminders and enabling voice-enabled personal assistants such as Amazon Alexa and Google Home received positive feedback from the CoP members. City council members emphasized the system's novelty: "Interesting to see technology interacting with one another, had initially thought these would have stand-alone operations.", and expressed interest in such technology in the health system: "We certainly see a place for products like this within social care.". Additionally, one frail and older CoP member mentioned that they would prefer voice instructions to silent ones; they found the synthesized voice instructions to be "alright" but would prefer a human voice.

The high level of personalization, in particular, received positive feedback from the CoP members: "It is helpful to program systems to sound like a family member. This helps in personalising the support provided to the customer.". It was also highlighted that older and frail people can encounter difficulties in using technologies (including voice-enabled personal assistants) due to lack of confidence and sensory and/or memory problems. Therefore, CoP members explained that personalisation is a key priority when considering technology for the health sector and mentioned that IntraVox can ensure individualized support.

CoP members stated that IntraVox could be a "phenomenal" solution in helping people adhere to a routine, especially when they are encouraged to conduct tasks related to everyday life. CoP members found the verbal prompts (e.g., wash the hand after going to the toilet, drink more water) to be useful and stated that the Activity Scenario could be useful for people with low motivation. However, CoP members also commented that IntraVox might only be suitable for mild and moderate dementia as the familiar and recognizable voice might confuse the user that the person the voice belongs to is physically present in the room.

Discussion

In this paper, we present IntraVox, a novel voice-based interaction system that introduces a highly personalized, human voice command between IoT devices such as smart home sensors, a Raspberry Pi computer, and smart home devices (e.g., voice-enabled personal assistants, smart lights, smart blinds, etc.). IntraVox is a low-cost effective solution that enables devices, sensors, and actuators to communicate wirelessly and send data to each other, avoiding the complexity of the end-user having to use multiple applications and engage with different processes. Based on the sensor data that is collected, the system uses a human voice to send prompts and reminders to users to conduct various tasks and commands to a voice-enabled personal assistant.

The research conducted in this study highlights the importance of an initial understanding of what end-users need and prefer. Results show that it is important to include multiple stakeholder categories in an iterative design and evaluation process and to apply co-design methods with potential end-users to not omit any desired functions. Although we initially designed a silent system and a solution using a computerized, synthetic voice for sending the voice commands, one CoP member suffering from a cognitive disability highlighted that these might not be appropriate for certain user categories. Based on their recommendations, we developed IntraVox.

Smart home technologies, such as smart home sensors and devices (e.g., smart blinds, smart lights, voice-enabled personal assistants) can support the daily activities, enhance independence, and improve the quality of life of many user groups. These off-the-shelf Internet of Things devices, in particular voice-enabled personal assistants such as Amazon Alexa and Google Home, can transform the lives of older and frail adults by allowing them to set reminders, ask for information or control various home technologies such as lights, temperature, and automatic blinds on their behalf. Despite the benefits, some users encounter difficulties in interacting with such devices due to the non-conversational style these devices are adopting. Having to recall keywords and specific syntaxes to enable the devices and trigger commands and the short amount of time in which these need to be spoken can constitute a problem for people with cognitive issues. IntraVox, on the other hand, improves the usability of voice-enabled personal assistants by removing the necessity for the user to remember and pronounce specific commands whilst also reinforcing the syntax and the usefulness of those commands.

IntraVox also gives users insights into what is happening in their homes and by using a familiar and recognizable voice to provide reminders, prompts, and commands, it also combines functionality with personalisation. Assistive technology interventions can be effective. However, they need to be flexible and customized to the individual (Dawe, 2006, Salai et al., 2021). It is important to personalise interventions as there cannot be a generic, one-size-fits-all approach to social care (McGee-Lennon and Gray, 2007). With this in mind, the two IntraVox solutions that we identified are highly personalized to the individual's home and tailored to their needs.

Agility is also key to optimising the use of everyday technology to support frail and older people in their homes. Both IntraVox solutions are agile; as the purpose evolves, these can be changed in response to reflection and assessment of the end-users needs. For instance, we were initially focusing on IntraVox sending smart home commands to voice-enabled personal assistants which in return would control smart home devices and processes. However, in the height of the COVID-19 pandemic, it was highly important that IntraVox could provide reminders and prompts for those with memory problems to wash their hands regularly. This change was easily implemented by simply changing the position of sensors and re-programming the message provided by IntraVox. This agile feature of IntraVox can be embedded in an individual's habitual practices and ensures multi-functionality and responsiveness to ever-changing needs, lifestyles, and health conditions.

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