The Doorbell Aid
FalconJAM

https://youtu.be/xVRq157hdDw

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Abstract

The purpose of our project is to create a doorbell-like mechanism that benefits people with hearing loss in the workplace environment. The mechanism sends and receives messages from two main components—a touch screen that replaces the doorbell, and a computer interface, where the messages are read from inside the office. It can record speech from the touch screen component and convert it into text which is sent to the computer, allowing employees with hearing loss to be alerted of a client at the door. The purpose is to create a device that allows for equal access in the workplace for individuals with hearing loss, as well as creating a product that *all* employees may utilize.

A | Statement of Problem

Our Subject Matter Expert (SME), Lise Hamlin, is an employee at the Hearing Loss Association of America (HLAA), and like many of her coworkers, she has hearing loss. At the workplace, communication, especially between someone outside the office door and someone in the office, could be very difficult. There are many types of assistive technology for impaired hearing such as hearing aids, cochlear implants, and the audio induction loop system that works with these devices. Nonetheless, coping with a hearing loss in the workplace can be difficult particularly if employers are not willing to provide assistive devices.

For some people, hearing the doorbell is not possible, causing communication issues. Each time we met with the HLAA, we faced an interesting problem: we would always wait at the door, waiting for a coincidence to occur, in which an employee would see us through the window. In any other circumstance, this could be an extreme waste of time and could cause stress to the office's clients. Our device attempts to mitigate this issue by using a touch screen doorbell and a computer program. When a visitor presses a button on the touch screen, a window pops up on the device of the employees where the program was installed. The visitor can also select a button to record a message (for example, "I am your repairman"). Their speech is converted to text and displayed on a pop-up window on any computer in the workplace. This way, a visitor at the door can notify and communicate with someone within the office, particularly with a hearing loss. It saves time so that the employees with hearing loss don't need to constantly check the door if they're expecting a client, like for an important meeting.

This increases workplace productivity because normally, the employees with hearing loss cannot hear the doorbell. If the employee is in the office alone, they may not know there are people at the door at all.

Lise Hamlin sometimes works during the night or on weekends when the receptionist is gone. With our new doorbell system, Lise is able to work more efficiently without others in the office, increasing the hours she can work. This increases worker productivity, as well as reducing the stress of both Lise and potential clients.

To summarize, our doorbell tackles the issue of lost productivity and reduces the time between ringing the doorbell and having someone answer the doorbell, saving lost time in the workplace.

B | Background

Hearing loss, impacting over 5% of the world's population and more than 48 million people in the US, manifests itself in many forms. For most, it develops in adulthood, and only involves a partial loss of hearing. Because of this, sign language can be an ineffective form of communication for many who experience a hearing loss. In many cases, hearing loss is caused by overexposure to loud noises, causing damage to the hairs and nerves in the inner ear that are responsible for sending signals to the brain. Others may experience hearing loss as a result of viruses or diseases. All in all, factors of hearing loss can be defined as either conductive or sensorineural. Conductive hearing loss results from problems with the ear canal or ear drum. Sensorineural hearing loss is nerve-related. These factors can be experienced separately, or in a combination (America, H. L.).

The two most common devices used by people with hearing loss are hearing aids and cochlear implants. A hearing aid amplifies sound and projects it to the ear. Cochlear implants are typically for people with more severe hearing loss. They require a surgical implant of one component which can connect to an external component through a magnetic disk. Instead of amplifying sounds, this implant stimulates the hearing nerve, directly sending signals to the brain (Mroz, M.).

Aside from these two devices, there are other technologies that can be used in the workplace. The hearing loop, developed in 1937, consists of a wire that runs around the perimeter of a room and sends electromagnetic signals to a sound system. These signals can be picked up by a component in most hearing aids and cochlear implants if the function is enabled. Hearing loops are often used in conference environments, which our team was able to experience in many of our meetings.

As for doorbells for people with hearing loss that notify them of visitors, many involve the use of a flashing light which produces a bright light when the doorbell is rung. The disadvantage to this is that the employee will only be notified if they're in a room with those lights installed. Another option is a doorbell with an extra loud chime so that people who have hearing loss but aren't deaf will be able to hear it. However, this is not suitable for the work environment as the excessive noise could disrupt other employees.

Unfortunately, many assistive devices are not well known, and some employers are not willing to implement these in their workplaces because they're relatively expensive and serve specific purposes for only specific people. The implications of hearing loss are not well understood by others. The parent of one of our team members has hearing loss, giving him new insight on the disability. Working with the HLAA allowed him to directly understand the impacts of hearing loss at the workplace, which are typically hard to understand from an outside perspective.

In an interview, Lise informed us about a friend whose boss would speak to her from another room. Many people with hearing loss rely on lip-reading to communicate, making the boss's behaviors difficult to work with. According to Lise, many of the problems in the workplace can be solved through simple changes in behavior.

Through conversations among people at HLAA and our teammate's family member, we learned about the hardships that people with hearing loss face, especially in a work environment. We hope to learn more about the disability and attempt to mitigate this serious issue, by normalizing the use of assistive technology in the workplace.

C | Rationale

The second time we met with our organization, the only person in the office was Ms. Hamlin. Unfortunately, after ringing the doorbell, we were unable to enter until another employee arrived to work for the day. Her arrival was purely coincidental, and in another case, we may have been left unattended for longer. This instance could have happened to any other visitor. With our improved doorbell design, this problem is solved.

Our doorbell system allows communication between the person at the door and the employee in the office. The connection is established via the internet. A touch screen is mounted at the office entrance, displaying three buttons: “I’m here for a meeting”, “I’m here for a delivery”, and “Press to record a message.” Each button will send a message to computers in the workplace. By selecting “Press to record a message,” individuals can speak into a microphone, and their words will be translated into text, which will appear on the computers of the employees, similarly to the words, “I’m here for a meeting”, or, “I’m here for a delivery”. Employees from the office can then respond back, typing messages to the doorbell.

This new process allows the workers to be notified when someone is at the door and also maximizes communication. Employees become more efficient and independent because individuals like Lise can work comfortably on weekends or nights when the receptionist is absent. Moreover, they become equally as informed as their coworkers, leveling the playing field.

With the added communication abilities, there are *additional* increases in efficiency that can apply to anyone, regardless of their hearing ability. As a result, the system can also be beneficial to people without hearing loss as well, making it viable to everyone in the office, not just employees with hearing loss. This allows employers to justify the purchase, making assistive technology more readily available. The technology can also be implemented at home because similar issues with hearing the doorbell are present in people’s homes as well.

D | Development

Our initial design was similar to the current design, with a few exceptions. We had planned to include a video camera, similar to other security doorbells, but we decided that the camera was unnecessary, as the main purpose of our product was to alert the employee. Moreover, a camera would have also added an unnecessary cost to the design.

We had also wanted to use an Arduino with a WiFi shield as the processing unit for the touch screen. An Arduino is a microcontroller: a small computer designed to complete a single task. The WiFi shield was an addition that would allow the Arduino to connect to the internet. Unfortunately, after some testing, we realized that the internet connection—which was necessary for communication between the doorbell and the computer application—was extremely unreliable using the WiFi shield. Thus, we decided to switch to using a Raspberry Pi: a microcomputer. The Raspberry Pi has integrated WiFi, making it much more reliable and flexible. Though this change was at the cost of a higher price, the cost is worth the added value of constant internet connection.

Our second main revision was changing the communication model for our doorbell. Initially, both the doorbell and the computer interface read from and wrote to Google Sheets as a way of accessing messages sent from either side. It was also used as a database because Ms. Hamlin wanted to keep a record of all the messages. However, after extensive testing, we

decided that sending the data through Google Sheets was too slow and power-consuming. Google Sheets also prevented the programs from reading from and writing to it after a certain amount of time. We ended up abandoning the original idea and switched to a different communication model—socket communication. The sockets in the two modules are connected through a specific computer port which allows for two way communication between the touch screen and the office computer with low processing power. This new model establishes the touchscreen as a server and the computer program in the office connecting to it as a client.

Dividing the tasks amongst ourselves, we created a Graphic User Interface (GUI) for the doorbell touch screen and a program for the computers inside the office. To hold the touch screen module at the door, we designed and built a box to contain the doorbell. Throughout the development process, we overcame many difficulties, including the calibration of the touch screen, finding a source of power, and the creation of reliable and user-friendly programs.

E | Patent Searches

To ensure that our project was original, we conducted a patent search. A Boolean word search was used to find similar products. Here are the results of our Boolean word search:

((((("speech-to-text" OR "raspberry pi") OR microphone) AND "hearing loss") AND "doorbell") | 27 patents

(doorbell AND ("impaired hearing" OR "hearing loss") AND "speech to text") | 0 patents

(doorbell AND ("impaired hearing" OR "hearing loss") AND "speech to text") | 0 patents

We found the following similar patents:

Assistive Implanted Devices:

> An alarm system for certain hearing impaired individuals having implanted hearing assistive devices contains a device for detecting an alarm condition, and a transmitter which is tuned to a resonant frequency of an implanted passive energy portion of a cochlear implant or similar device. Upon detection of an alarm condition, the transmitter transmits an alarm signal at the resonant frequency, causing the implanted device to resonate even in the absence of the externally worn hearing assistive portion. Resonance is perceived by the hearing impaired individual as a buzzing or other abnormal noise, alerting the individual to the alarm condition.

General Purpose Device to Assist Hard of Hearing:

> An approach to notifying a person who is hard of hearing of audible events based on a configurable device. The device has microphones and associated buttons mounted on its surface. The user programs the device by depressing a selected button longer than a preconfigured time to place the device in listen mode. The user generates the desired audible event and the device records the audible event. The selected button is depressed again to instruct the device to associate the audible event with a visual alarm indicator of colored/flashing lights and/or a text projection. The device listens for the audible event and activates the visual alarm indicator when the device detects the audible event.

Doorbell System and Doorbell Chime:

> A doorbell system comprises a doorbell chime (18), a first doorbell push (10) for sending a first input signal to the doorbell chime (18) in response to the first doorbell push (10) being activated, and a second device, such as a second doorbell push (14), for sending a second input signal to the doorbell chime (18). The doorbell chime (18) is arranged to emit light (24) of a first color in response to receiving the first input signal and light of a

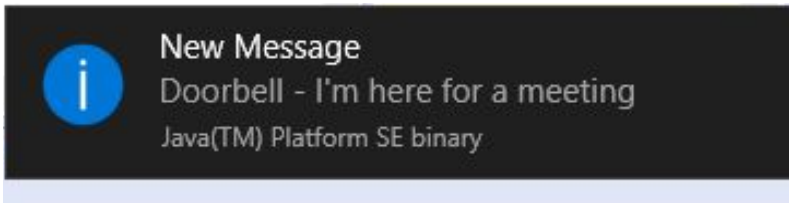
second, different, color in response to receiving the second input signal. The light (24) may be emitted around a perimeter of the doorbell chime, such that it creates a halo effect around the part of the door chime located within said perimeter.

Although our design shares the intent of these patents, none of them provide a speech-to-text option, or individual messages that can be communicated from the visitor to the employee. Thus, our product is original and unique.

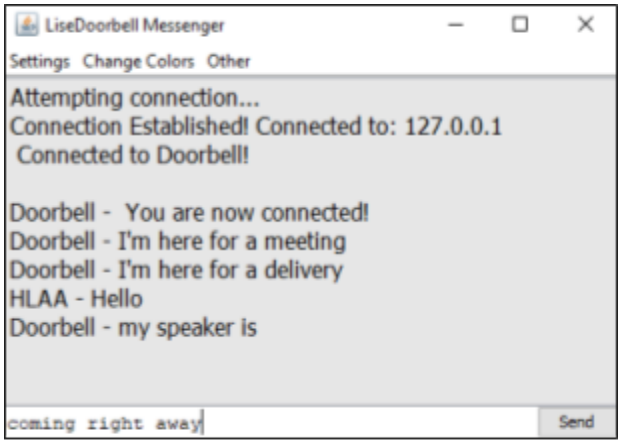
F | Final Design

The final design is an amalgamation of many programming languages and hardware components. The doorbell consists of a Raspberry Pi, a touch screen, a microphone, and a wooden box to hold it all. Inside the box, the touch screen and microphone are connected to the Raspberry Pi and holes in the box allow the touch screen to be viewed and the microphone to detect audio.

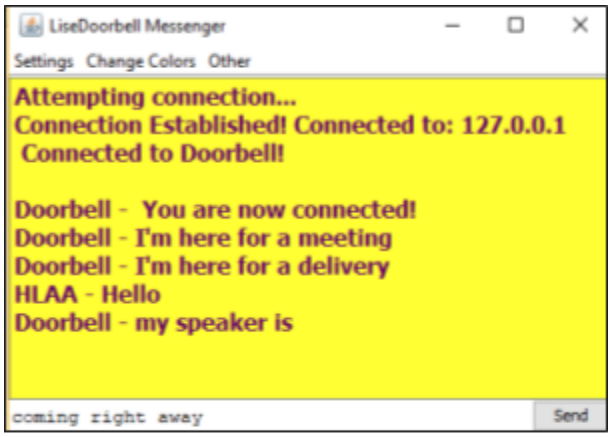
On the touch screen interface, two of the buttons—"I'm here for a meeting" and "I'm here for a delivery"—send built-in messages to the computer interface. Preloaded messages can easily be changed to other text as the HLAA desires. If the third button "Press to record a message" is selected, the microphone records the user's voice and processes it through a speech-to-text program that uses the Google Speech API. The resulting text is delivered, like the messages from the other two buttons, through a socket connection to the Java program on the employees' computers. Messages can be sent back and forth until one program is closed.



Sample notification on office computer



Computer Interface



Computer Interface (after changing colors and font)

There are many features to our computer program. Not only is the employee able to type back a direct message which would display on the touch screen, but they can also save the entire conversation into a text file for recordkeeping purposes.

Moreover, the background color, text color, and font size of the messages can be adjusted to one's liking, benefiting those with partial vision loss, as certain color combinations are easier to read for some people. For example, some fonts are easier to read by individuals with dyslexia. Others may prefer to have more contrasting colors between their text and background. Our device is also helpful for employees who do not have hearing loss because they can send a message directly to the door before going to open it, to ensure that the client knows that an employee is coming to get the door. All of this makes our device incredibly accessible to a wide demographic, furthering the presence of assistive technology in the workplace.

The doorbell module also has some features to guarantee higher efficiency. For one, before the speech-to-text message is sent out, the program asks the user to verify that it is correct to prevent any errors caused by the speech recognition. To prevent the doorbell from overheating and damaging the electronic components, we added heat sinks to parts of the Raspberry Pi and added air vents to the back of our box.

G | Cost Analysis

Our materials included in the final design are the Raspberry Pi ($34.99), microphone ($5), touch screen ($25.99), command strips ($2) and wood (approximately $1). The programs required include Java 1.7, Python 3 (or higher), and the Google Speech API. These programs are free to install and use. Thus, the total cost of materials for the final product is about $69.

In our design, prototyping, and building process, we used additional programs such as Inventor and the Arduino. Fortunately, our team had free access to Inventor through our school. Moreover, one of our team members owned an Arduino, which reduced the total cost that we spent throughout the project.

In a mass-production environment, the cost would be significantly reduced. This is mainly because the Raspberry Pi is tremendously powerful, and many of its functions were not needed for our product. The creators of the Raspberry Pi also offer models that contain only the

features we need at a much lower price, For example, the Pi Zero W costs $10, which would lower the final product's cost to $44.

Even so, the price of our product is reasonable when compared to similar devices. Normal audio doorbells can cost up to $20, even without speech-to-text or visual notifications. Doorbells with flashing lights, which can be very ineffective, can cost up to $80 ("Hearing Impaired Alert Devices, Bed Shakers, Doorbell Signalers and Medical Alert Systems"). This does not include a touch screen interface or computer alert program. Because our product provides additional benefits, its manufacturing price is easily justified.

As previously stated, when the benefits of our doorbell extend to *all* people in the workplace, employers are more willing to purchase the product. This makes our doorbell far more accessible than other doorbells with visual alerts.

Material	Cost
Raspberry Pi	$34.99
Microphone	$5.00
Touch screen	$25.99
Command Strips	$2.00
Wood	$1.00
Total	**$68.98**

H | Testing Procedure and Results

During the testing process, we collected and made use of both quantitative and qualitative data. The qualitative benefits are clear: before using the device, employees with hearing loss could not hear their doorbell, and the visitor would be left unattended unless a hearing person was also in the workplace. With our product, employees with hearing loss were notified of visitors and could act accordingly.

It is hard to gauge the time it took to open the door before our doorbell device as we can only get a rough estimate based on personal experience. Before every meeting, we used a timer to find the amount of time it would take for us to be welcomed into the office. After three meetings, the average amount of wait time without our product was 2.5 minutes. For unexpected visitors, this time could be extended for much longer and could be stressful for a potential client.

Next, we used a timer to record the efficiency of our product. By averaging multiple data points, we are able to get a rough estimate of response time. After multiple tests, we observed that the average time it took to receive a notification and respond to the door was 10 seconds, as employees can respond through a message from the computer program back to the doorbell. Thus, the time it takes to respond to the client using our device was 15 times less than it had been.

For a client at the door, sending preloaded messages is instantaneous, and the process of sending speech to text messages takes under 10 seconds, mainly because of the time it takes for a user to speak into the microphone. One important fact to note is that this test does not account for the time it takes for someone to actually see the message on the computer as such a test is

impossible to conduct, but most members work primarily on their computers, so we assumed that this lag time is minimal.

To collect additional data and feedback, we created a simple questionnaire that asks Lise questions about our product and its usefulness. The responses were mainly used to troubleshoot any bugs with the software.

I | Community Impact

The Bethesda office of the Hearing Loss Association of America has a unique community that would benefit *extremely* from this device. Their receptionist is often unavailable to open the door for visitors. Many of the employees with hearing loss also work on weekends or after hours, in the absence of coworkers who can hear. With these two issues in mind, a device that notifies the employees on their computers is well-tailored to this environment. Moreover, the potential impact in other workplaces is even greater.

In most cases, concerns from employees with hearing loss are not recognized in their workplaces. Their employers may be unsympathetic to their needs, and the litigation required to implement assistive devices in a hearing workplace can be convoluted, lengthy, and costly. To put it simply, our device serves two functions: alerting employees (particularly those with hearing loss) and providing a new layer of communication. This provides benefits to all members of the workplace, with or without hearing loss. Consequently, employers are more likely to purchase a device that serves *all* of their employees, bridging the gap and increasing independence for those with hearing loss. Finally, it normalizes the use of all-inclusive technology in the workplace, a key component to breaking down stigmas surrounding disabilities.

J | Conclusion

Overall, the Doorbell Aid is a cost-effective method of bridging the gap between the hearing world and those without hearing, especially in the workplace. In the Hearing Loss Association of America, it allows employees like Lise to fully participate in the office and work independently on weekends and after hours. Throughout our visits to HLAA, we showed our product, explained the development process to get input directly from Lise, and tested the actual application of the device. Our initial visits focused on learning about hearing loss and pitching ideas. From there, we were able to build a product tailored to Lise's specific needs. Lise and all other employees at the office are very happy with our device and it will definitely benefit their workplace. Outside of this organization, our product provides an assistive device that is significantly more accessible to those with hearing loss, and refines older techniques that are less efficient, including doorbells with flashing lights, vibrations, or extremely loud chimes. Furthermore, the ability to customize the interface allows further accessibility to individuals with other disabilities, including partial color blindness, poor sight, or reading disabilities. Because of its clear applications to our client organization and workplaces beyond our project's scope, the Doorbell Aid has the potential to shape the work environment for countless employees with hearing impairments.

K | References and Acknowledgements

We would like to acknowledge the employees at the Bethesda office of the Hearing Loss Association of America, particularly Lise Hamlin and Nancy Macklin. We would like to thank

Ms. Macklin for serving as our initial point of contact and supporting our endeavors by introducing us to the community in her office. We would also like to thank Ms. Hamlin for being a wonderful subject matter expert and mentor. Despite many trials and tribulations, she was extremely supportive and enthusiastic throughout the process, which made a clear difference in motivating us to complete the product. After meetings with Lise, we left feeling rejuvenated and enthusiastic about continuing our project, despite the major obstacles we encountered. However, the most important educational experience was listening to Lise's experiences as a person with hearing loss, and we consider ourselves extremely fortunate to have had the opportunity to work with her.

We also would like to thank our parents and our teacher, Mr. Curran, for providing additional support and advice while combating issues we encountered during our development process. Finally, we would like to thank SourceAmerica for providing us with the wonderful opportunity to create a positive impact on our community.

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