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SOUTHEASTERN TRANSPORTATION CENTER

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16. Abstract Mobility and transportation are key elements of staying active in the community, especially elderly citizen and citizens with disability who choose to *age in place* and are most reliant on public transportation. From a previous study, Industrial and Systems Engineering (ISE) along with Community Action Committee (CAC) concluded that one of top barrier hindering or preventing seniors and the disabled from using public transportation was their inability to ask the bus drivers basic questions about the transit. Bus Helper (Project ERIC) is a mobile application is an Android and Apple platform based App designed to assist passengers who are elderly, have disabilities (vision, hearing and cognitive) and do not speak English ensure they have a safe, comfortable and convenient way of travel.		
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EXECUTIVE SUMMARY

The University of Tennessee Department of Industrial and Systems Engineering (ISE) has developed over the last two year key partnerships that have facilitated the research and implementation of the project. These partnerships include the three major transit agencies with (CAC, KAT and ETHRA), the Knoxville Regional Transportation Planning Organization, the City of Knoxville and various state and private social agencies such as the Department Of Intellectual And Developmental Disabilities and Knox County ADA Committee. Their insight and support has provided the necessary framework to collect data, provide access to participants of the transportation system, and to provide feedback on results. From previous joint study Industrial and Systems Engineering (ISE), along with Community Action Committee (CAC), concluded that one of top barrier hindering or preventing seniors and the disabled from using public transportation was their inability to ask the bus drivers basic questions concerning destination, timeliness, and personal matters such as safety and general comments. Addressing the communication barriers for citizen who are elderly or disabled while using public transportation via Bus Helper (Project ERIC) mobile App can ensure they have a safe, comfortable and convenient way to travel like every other citizen.

Bus Helper (Project ERIC) is a mobile application is an Android and Apple platform based App developed by Industrial and Systems Engineering (ISE). It is designed to assist passengers who are elderly, have disabilities (vision, hearing and cognitive) and do not speak English. The App will become a source of communication for passengers with limited speech, as there is no other previous means of communication existing for the passengers with limited communication. The developed graphical user interface of the application helps to access information from the database of collected predefined communication phrases, so that the user can search for a specific question that he/she requires to communicate with the bus driver and access it. The application has adopted different forms of interfaces to help with different accessibility needs of the passenger while using the tablet. The user interface design is around the idea that text, picture and speech will be useful to majority of the population with limited communication. Project Eric application has four kinds of accessibility interfaces: 1) Hearing 2) Vision 3) Cognitive 4) Non-English Speaking

DESCRIPTION OF PROBLEM

Mobility and transportation are key elements of staying active in the community, especially elderly citizen and citizens with disability who choose to *age in place* and are most reliant on public transportation. (Abdul Karim & Nwagboso, 2004). A study conducted to find effects of transportation on quality of life has found out that lack of transportation specifically not being a driver, has significant factors negatively associated with quality of life and providing alternative transportation has significant factors positively associated with quality of life (Kim & Ulfarsson, 2013). People with disabilities use public transportation for jobs, medical attention and socialization. Passengers who are elderly and with disabilities have different needs while riding the transportation. (Abdul Karim & Nwagboso, 2004). The majority of these people use paratransit services, which is a "demand-response" service in which a passenger must reserve a ride and will have door-to-door pickup and delivery. Three transit agencies in Knox County provide public transportation elderly and citizens with disability: CAC (Community Action Committee), ETHRA (East Tennessee Human Resource Agency) and KAT (Knoxville Area Transit). KAT provides both fix route buses and paratransit service; ETHRA and CAC are both paratransit service. From a previous joint study conducted by CAC and the ISE it was concluded that one of the top barriers hindering or preventing the disabled from using public transportation was their hesitance or inability to communicate to driver during the transit. Safety is particularly important since the passenger with a disability have difficulty in expressing concerns about a hostile environment, having defective safety equipment such as seat belts, inaccessible pull stop-cord, or insufficient tie downs for wheelchairs, and conveying concern about driver conduct (using phone while driving, speeding or other erratic behavior).

There are many assistive technologies developed for transportation to enable a safe and convenient transit experience. The MobiPlus system is an intelligent wireless bus-station interactive system with the integration of multi-wireless techniques (RFID, ZIGBEE, WIFI, and GPS). This system helps in detecting disabled, wheelchair and Blind (DWB) can connects to bus service system through wireless communication system (Hai-Ying et al., 2006). Safety of vulnerable people in public space has been addressed by the project SAVE ME (Systems and Actions for Vehicles and transportation hubs to support Disaster Mitigation and

Evacuation) to improve safety of transportation infrastructure.(Marsella, Delprato, & Marzoli, 2010). Services considered for elderly are assisted living services (ALS) including health and emergency needs and assisted mobility services(AMS) with transportation needs (Nam & Kwansu, 2007).

APPROACH AND METHODOLOGY

1. *Data Collection:* Data collections consist of exploring the communication barrier existing between passenger and driver during the lifecycle of transit, from 579 elderly and passengers with disabilities in 27 groups (Table 1) within five counties (Anderson, Blount, Knox, Loudon and Union). Data collection uses two approaches:
    a. Meeting in the Box (MIB): The MIB concept was cultivated by Plan East Tennessee (PlanET) to take meetings to desired participants,
    CAC along with ISE tailored this concept to reach out to elderly and people with disabilities. Conduction of MIB meetings took place by contacting organizations and support groups servicing specific demographics and requesting presentation time at one of their regularly scheduled meetings or events. CAC hired outreach coordinator to facilitate the meeting by giving an overview of the project and administering a written survey followed by a group discussion. This generous opportunity gave participants the advantage of meeting in a familiar place with others they see on a regular basis. During these discussions, participants shared their individual transportation communication concerns. CAC shared MIB meetings information with ISE and ISE directed the questions asked during the group discussion. During thirty-one MIB sessions, 441 elderly and people with disabilities have participated.
    b. Online Surveys
        i. Passenger: A developmental passenger survey was prepared from MIB sessions and posted online on a public domain:

https://www.surveymonkey.com/s/round2tp4all, which received 140 responses.

ii. Driver: A developmental driver survey was prepared from MIB sessions and posted online on a public domain: https://www.surveymonkey.com/s/round2driversurvey, and distributed to the three local transit provider providers [CAC, ETHRA and KAT]. Driver survey received 65 responses.

Table one: List of organization or support groups

Campus Disability Advocates	Pleasantree apts.- Helen Ross McNabb	Helen Ross McNabb / Friendship House	Adult Day Services Union County
Cerebral Palsy Housing Corporation	Sertoma Center	Knoxville Center of the Deaf Senior Citizens	Grandparents as Parents
Daily Living Center (O'Connor Ctr)	Stepping Stones- Ridgeview	Tennessee School for The Deaf	Foster Grandparents
Douglas Cooperative	STAR Shangri-La therapeutic Academy of Riding	Low Vision Support Group	Senior Companions
Emory Valley C enter	The Gate	Patricia Neal Rehabilitation Center/Covt Health	Retired & Senior Volunteer Program (RSVP)
Goodwill - Kingston Pike	UT FUTURE Program	Goodwill - Pleasant Ridge	Foster Grandparents
Goodwill- Oakridge	Center of Hispano de East Tennessee	Low Vision Support Group	Senior Companions
Blind referral from Disability Resource Center	Loudon County Senior Center	Willow Ridge Care & Rehab Ctr.	

2. App System Architecture

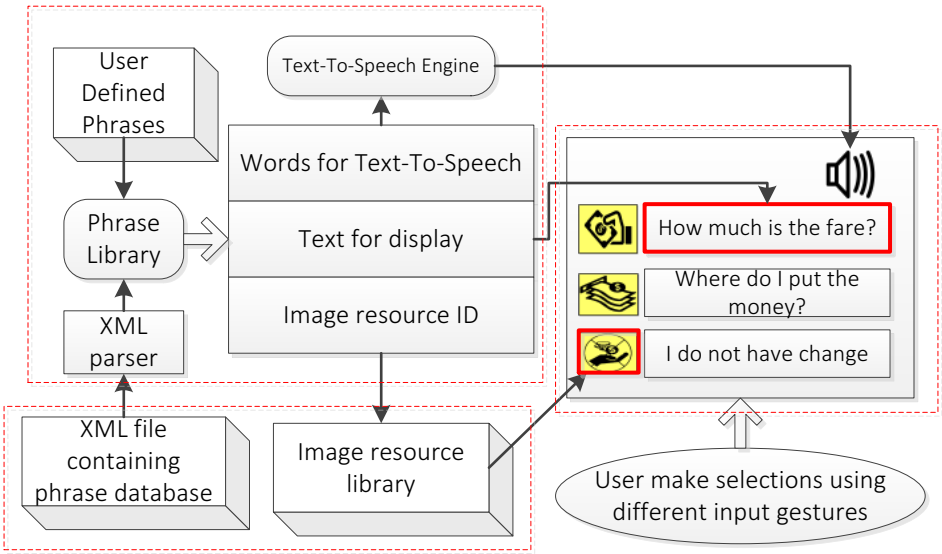

Figure 2.1 - The structure of the mobile application and the interaction between each component

The Bus Helper (Project ERIC) Mobile Application divided into a three-layered architecture. It has a user interface, a database that stores contents, and an interpreter that reads the content from the database, interprets the information, and sends them to the user interface.

As shown in figure 2.1, when the mobile application starts, the XML parser will load the phrase database stored in an XML file, extract the phrase items recursively, and then store them in memory using a tree structure. Each item will contain several types of information in a key-value format; this information is use to display proper content in the user interface. Since all contents in the database are now stored in a tree structure, the user's actions can be mapped precisely to the tree operation.

Using a three-layered architecture, the system can be decouple into relatively independent components, and the change of each component will not affect the functionality of other components. This architecture guarantees the extendibility, flexibility, maintainability, reusability and portability.

The mobile application does not use the client/server architecture; instead, it uses a standalone structure. This architecture choice is mainly for two reasons: reliability and easiness of use. This mobile app use on the public transportation system better accommodates the elderly and passengers with disabilities, where Wi-Fi connection is not always available on the moving vehicle. Besides the network condition, there are also risks that the server may fail and the client cannot work properly if the contents are stored in the server. Under this circumstance, phrases stored in database on the local storage of the mobile device, ensures reliability regardless of the network availability.

3. *Component Design*

   The information domain of bus helper (Project ERIC) system consists of different types of information, which includes the types of disabilities, all

phases during the life cycle of using the public transportation, and the categories of the phrases as listed below:

- Vision - Disability type, the passengers who are blind or vision impaired
- Cognitive – Disability type, the passengers who have developmental disability or intellectual disability or mental illness
- Non-English – Limitation, the passengers who are with or without disabilities and cannot speak or understand English
- Hearing/Other – Disability type, the passengers who are deaf or hearing impaired, or with other uncounted problems like aging.
- Getting on – A phase in the lifecycle of transit where the bus arrives at the bus stop and passenger boards on the bus and gets seated
- Getting off – A phase in the lifecycle of the transit where the passenger reached her/his destination/destined stop and is preparing to leave the bus
- Travelling – A phase in the lifecycle of transit between the getting on phase and the getting off phase
- General information – phrase category, this type of phrases is general and has no special emphasis
- Trip information – phrase category, this type of phrases emphasizes on querying the information during the trip
- Safety – phrase category, this type of phrases focuses on the safety related questions
- Comfort – phrase category, this type of phrases mainly concerns about the comfort of the passengers
- Home Page – This is the screen where users can find the four usability interfaces, namely vision, hearing, cognitive and non-English speaking. See Figure 3.1.
- Main Menu – This is the screen where the user can find the four transit phases, namely getting on, getting off, travelling and emergency in the hearing and non-English speaking component. The screen is at the tutorial page in the vision component. See Figure 3.2.
- Response page – This page is use to quickly access the most used phrases that the passenger would like to express to the driver.

Figure 3.1. Home page for Bus Helper

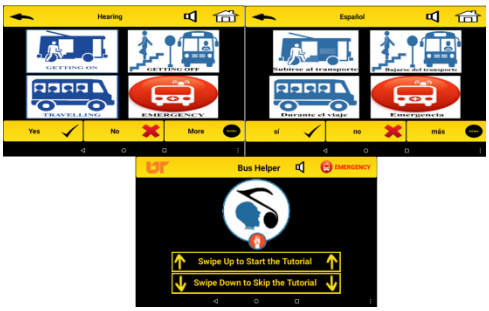

Figure 3.2. Main menu for hearing, Non-English and Vision part

The XML file has contents for display and speak out in the user interface that are stored in database. The advantage of XML data structure is that it is ease to expand, understand that makes any modification and addition of the content possible by non-programmers in the development team. Figure 3.3 demonstrates the detailed structure and example data.

```
<xml>
<General>
    <Item>
        <Title>To the Driver</Title>
        <Text>To The Driver</Text>
        <Image>picture133</Image>
        ......
        <Item>
            <Title>What is your name?</Title>
            <Text>What is your name?</Text>
            <Image>picture13</Image>
            ......
        </Item>
        ......
    </Item>
    ......
</General>
<Trip>
    ......
</Trip>
......
</xml>
```

Figure 3.3 XML file structure

The XML file will be loaded into the memory as a tree structure linked list. As shown in Figure 3.4, each node of the tree has a data part and a child part. The data part consists of all the information required in the user interface, like the title of the item, the text for speaking out and the corresponding displayed icon image. If the current item is a categorical item, which means there are more items under its category, then the children part will be a pointer of an array of items; otherwise, if the current item is a final node with no more items beyond it, the child part will be null.

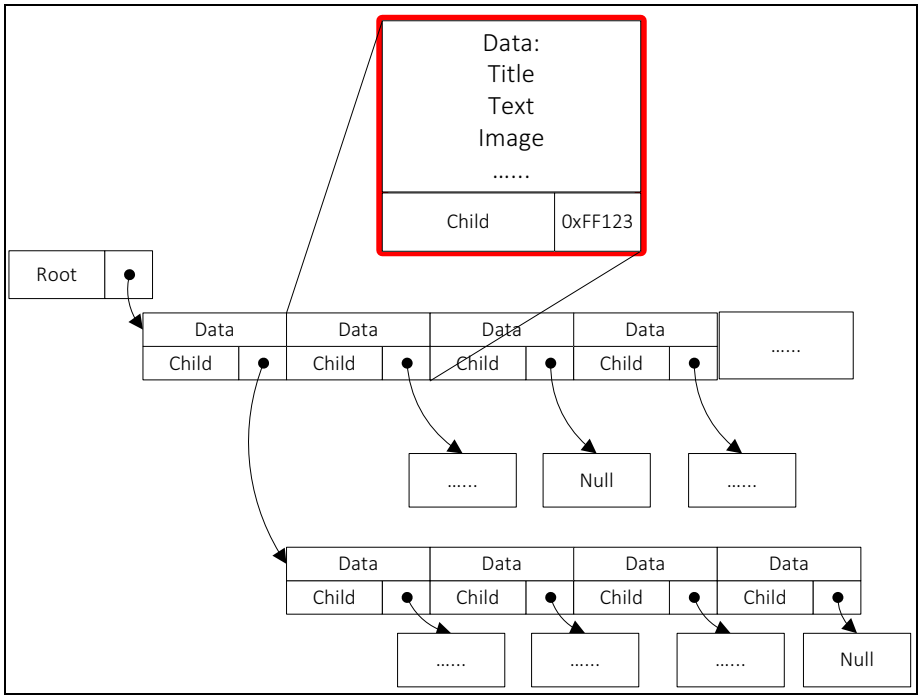

Figure 3.4 Tree structure loaded from the XML file

The developed phrase database is from the data obtained through surveys. An exception for having additional phrases that do not exist in the database is always a possibility. To handle such scenarios a user input functionality is available in the App. The user can find the "Input Your Text…" option, which allows the user to type in the customized phrase. The phrase can then be added to the phrase library, and can be accessed and spoken out when applicable. In the phrase library, the user-defined items have a special field that differentiates them from other system-defined items. The user can delete items if they consider it no longer necessary.

Tutorials are available to get users familiar with the App. Two types of tutorials are available on the App for different types of functionality in accordance to user's limitation. The tutorial used for people with deaf/hearing impaired/non-English speaking is a list of screenshots with highlighted areas and description text together with voice guidance. The tutorial used for blind/vision impaired is an interactive voice guidance that instructs the user to perform each operation systematically as the user inputs each step. Once the user performs the actions as instructed, the tutorial will proceed to instruct her/him the next operation, until the entire tutorial finishes. This interactive tutorial will enable the users with impaired vision to understand and remember how to operate this mobile app while no extraneous training cost is required. There is no tutorial for cognitive impaired users as understanding and memorizing is an issue.

4. Human interface design

The user interface design is similar to the standard android interface and designed around the idea that text, picture and speech will help 80% of disabled individuals with their

communications. This information is from a face-to-face interview with a speech therapist. The entire app developed within seven colors (Black, White, Yellow, Blue, Red, Purple and Green). The flow of the interface designed around the idea of searching for a specific question and being able to access it.

The flow information follows the lifecycle of transit (getting on, travelling and getting off). Questions relevant to each of these phases are only visible under them. Since the accessibility of tablet passengers with various limitation due to aging or disability is different, the apps has three kinds of interfaces:

a. Hearing

   This component of the App designed to assist passengers who are deaf or hearing impaired so that the App becomes their voice over during their communication with the driver on the bus. The 'Hearing' component uses five colors (Black, White, Yellow, Blue and Red) for the display of information. This component is entirely accessible by double clicking the button so that the button not clicked without the user's knowledge. Hearing limitations of the user makes it difficult for her/him to understand that the button is working when he/she has double tapped the button and hence an animated speaker icon is available on the App to help in this situation. A suggestion from the students from the deaf school lead to the inclusion of 'Text to Speech' feature for passengers to communicate more than what is available in the App. The following table summarizes the navigation in the 'Hearing' component

Navigation	
All questions and categories	Double Tap
Text Input Tab	Double Tap/On screen Texting
Speaker Animation	Speaker animation functions while playing the speech
Main Menu	House Picture Navigates to Main Menu page
Home	Tablet Back Button
Response Page	'More' Button on every page
Previous Page	Back Button

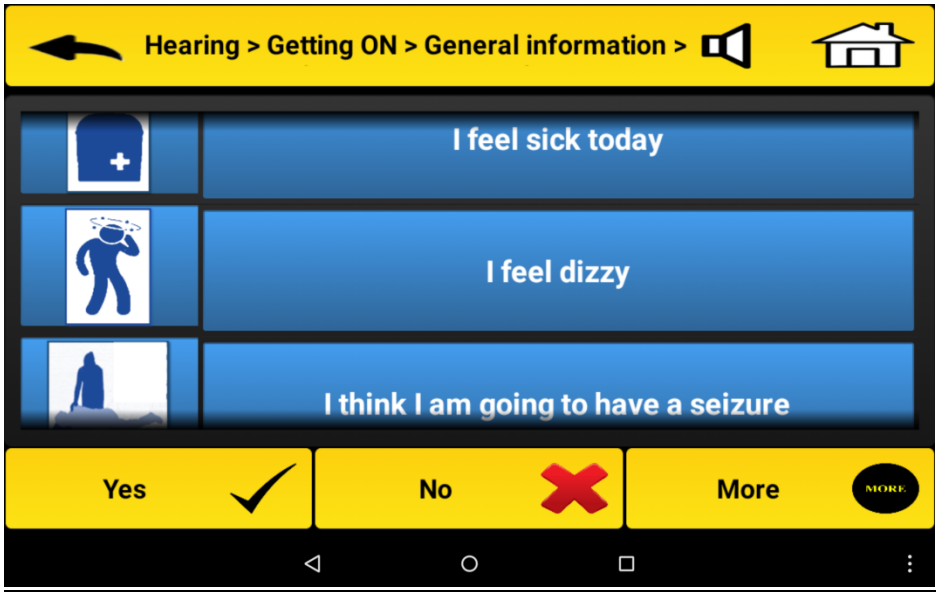

Figure 4.1: Screenshot of 'Hearing' component

b. Vision

This component of the App designed to assist passengers, who are blind or vision impaired and have speech difficulty, so that the App becomes their voice over during their communication with the driver on the bus. The 'Vision' component uses two colors (Black, Yellow) and text size is above font 18 for display of information as recommended by both vision impaired passengers and caretakers assisting the passengers. As passengers with vision limitation cannot locate the specific space on the tablet to tap accurately, a complete gesture based input guided by an interactive voice is available for accessing the 'Vision' component. Following table summarized the navigation of 'Vision' component.

Navigation	
Swipe	Left to Right - Right side navigation
	Right to Left - Left side navigation
	Up to down - Entering next level
	Down to up - Moving out of present level
Click	Double click - Yes
	Triple click - No
Home Page	External button on the tablet
Main Menu	Delayed Press with two fingers
Response Page	Delayed press with three fingers

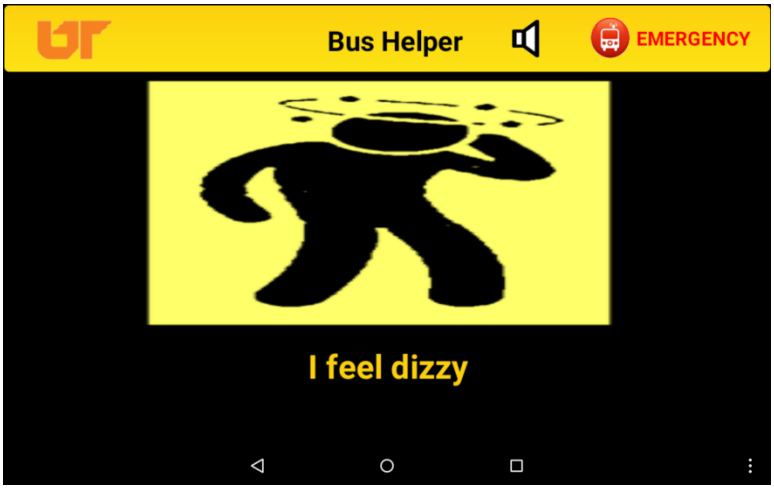

Figure 4.2: Screenshot of 'Vision' component

c. Cognitive

This component of the App design is to assist passengers who have developmental, intellectual and mental illness along with speech difficulty, so that the App becomes their voice over during their communication with the driver on the bus. The 'Cognitive' component uses seven colors (black, white, yellow, blue, red, green and purple) for the display of information. Since cognitively limited passengers have difficulty in information processing and memorizing the location of the information, the entire data is available under one single screen and accessed by scrolling. The buttons with the text on them need to be pressed for a specific amount of time to be able to access the specific information. A background voice continuously reminds passengers about the action to perform on the tablet every time he/she touches the tablet. The following table summarizes the navigation of 'Cognitive' component.

Navigation	
All questions	Scroll
Speaker questions	One finger Long Press
Speaker Animation	
Home	Tablet Back button
Response Page	'More' Button at bottom of the page
Previous Page	Back Button

Emergency button	Ambulance symbol at the upper right corner

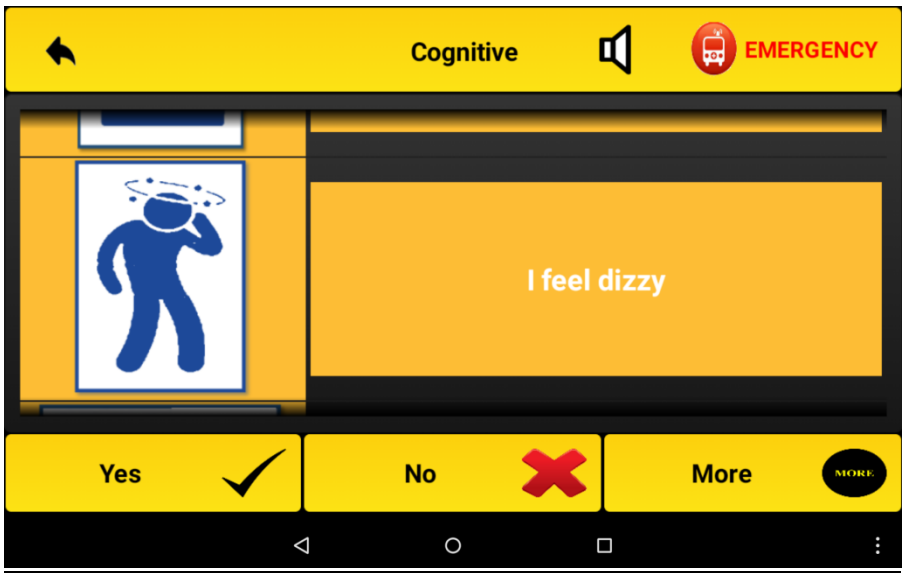

Figure 4.3: Screenshot of 'Cognitive' component

d. Non –English Speaking

This component of the App designed to assist passengers who do not speak English and have trouble communicating with the driver on the bus so that the App becomes their voice over during their communication with the driver on the bus. The 'Non-English Speaking' component is very similar to 'Hearing' component in operation but has Spanish text along with English text to help the passenger to select the specific communication and let the tablet speak it in English to the driver. For current version, only Spanish is available.

Figure 4.4: Screenshot of 'Non-English Speaking' component

FINDINGS

1) Diverse Disability: Participants who are elderly or have disabilities are the greatest resources in this project. They have voiced their feelings and shared their experiences that have opened doorways to our approach towards the application design. Through these discussions from "Meeting in a Box" sessions, our finding was that we could not treat any two organizations or disabilities the same for App design.
2) Occurrence of Vast Communication: The "Life Cycle of Transportation" defined as a passenger's trip from point of boarding to the dropping off at their point of destination. This life cycle of transportation divided into subcomponents like boarding, seating, traveling, reaching destination, and dropping off. Communication occurring between passenger and driver in each of these components, collected during the "Meeting in a Box" sessions has lead us into a findings that there is vast amount communication occurring between passenger and driver but there is essential communication repeatedly used by most of the passengers
3) Lack of Awareness of Familiarity of Technology: Outreach coordinator of CAC tested the tablet usage with few groups that previously participated in the MIB meetings by making them take the online survey. Participant were:
   1. People who had no previous computer technological experience
   2. People who utilized a regular computer to take the survey, and
   3. Persons who used the tablet technology to take the survey (which seemed to be the easiest application for all three situations).

   Our findings were that some of the participants struggled while trying to do the online survey using a computer, but found that using tablet-based technology was much simpler for them. Sensitivity of the equipment itself

has been an issue with some participants, which needed the use adaptive technology, like a pencil eraser or stylus for accuracy on the tablet.

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APPENDIX

Publications, presentations, posters resulting from this project: None